QCD Measurements at the Tevatron

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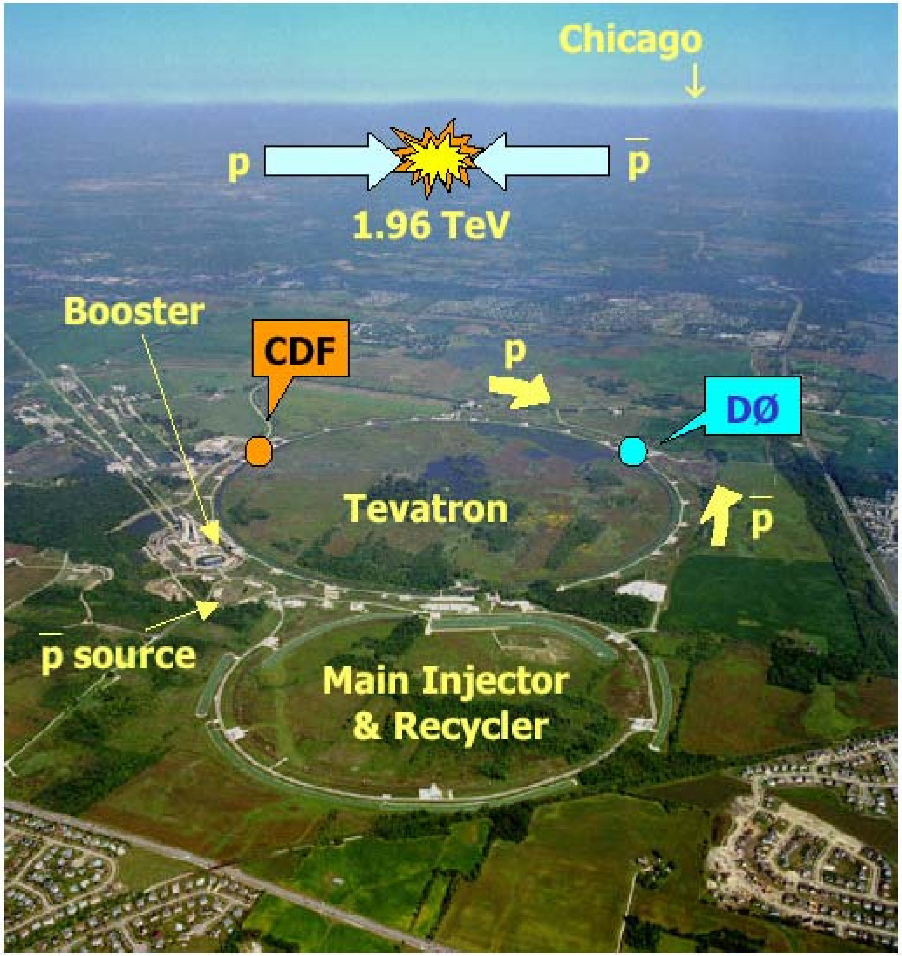
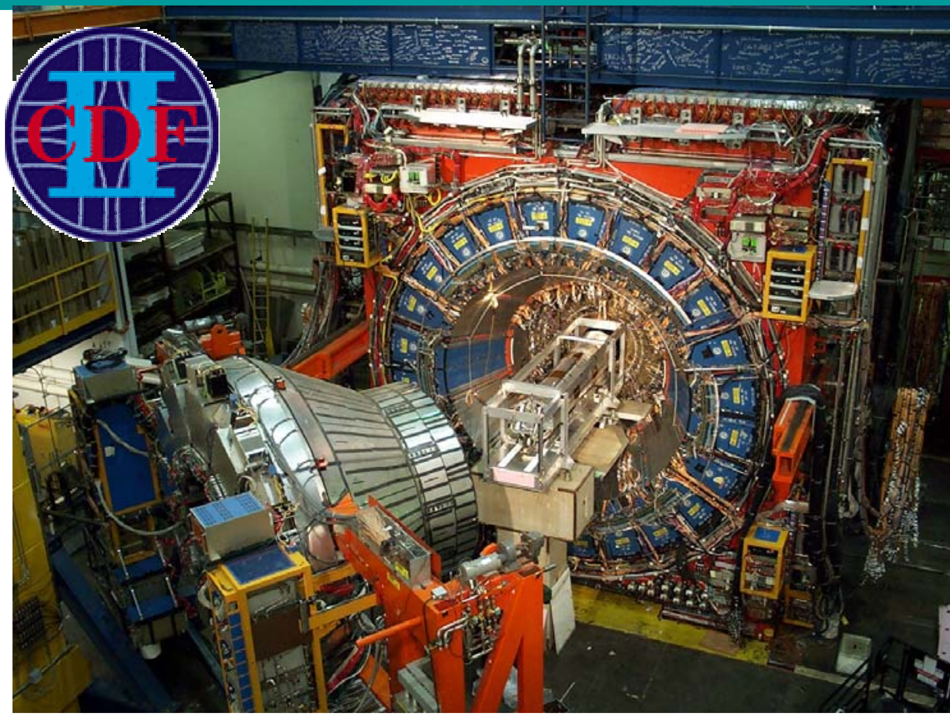
Some Tropical Picture goes here

The Tevatron Accelerator

- **World's highest energy collider (until 2007)**
  - **Proton-antiproton Synchrotron**
  - **Experiments CDF and D0**
- **Run I (1992-1996)**
  - **$\sqrt{s}$ = 1.8 TeV**
  - **6 x 6 bunches with 3 μs spacing**
  - **~100 pb^{-1} int. luminosity**
- **Major upgrade to accelerator complex**
  - **Main Injector (x5)**
  - **Pbar Recycler (x2)**
- **Run II (2001-2009 ?)**
  - **$\sqrt{s}$ = 1.96 TeV**
  - **36 x 36 bunches with 396 ns spacing**
  - **Current peak luminosity >15.0 x 10^{31} $cm^{-2}s^{-1}$ = 5 x Run I**
  - **Aim for 4-9 fb^{-1} int. luminosity in Run II – both experiments have now > 1 fb^{-1} on tape.**



CDF and D0 in Run II



Both detectors

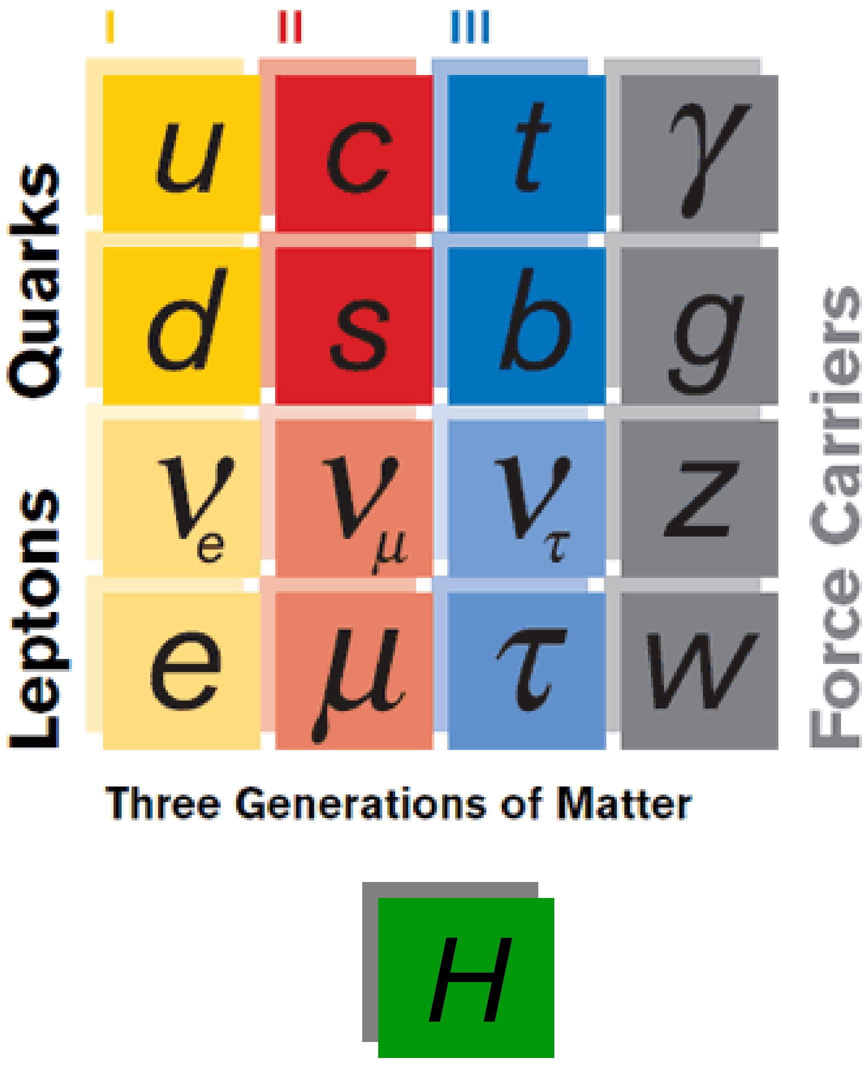
- •Silicon microvertex tracker
- •Solenoid
- •High rate trigger/DAQ
- •Calorimeters and muons

L2 trigger on displaced vertices
Excellent tracking resolution

Excellent muon ID and acceptance
Excellent tracking acceptance $|\eta| < 2\text{-}3$

The Standard Model

- Matter is made out of fermions:
  - quarks and leptons
  - 3 generations
- Forces are carried by Bosons:
  - Electroweak: γ,W,Z
  - Strong: gluons
- Higgs boson:
  - Gives mass to particles
  - Not found yet

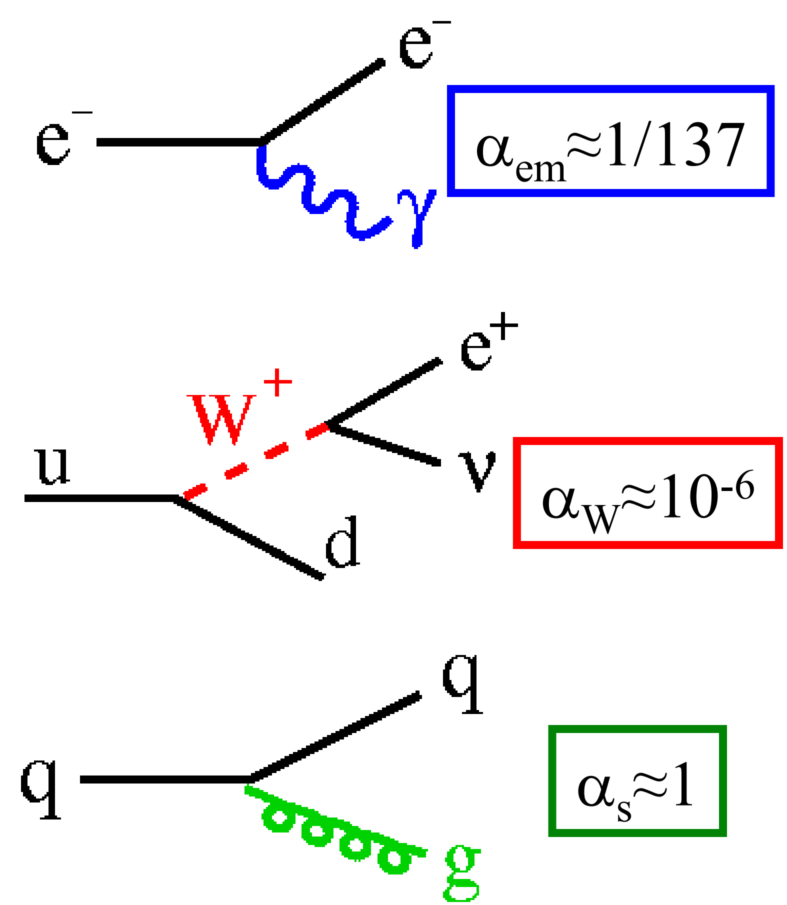


Electroweak And Strong Force

- Quantum field theory is used to describe forces of nature:
  - Unified description of weak and electromagnetic force (Glashow, Salam, Weinberg):
    - Photon
    - W, Z
  - Strong force described by Quantumchromodynamics (QCD)
    - 8 gluons
- Precision measurements test validity of model and calculations
- QCD has unique features:

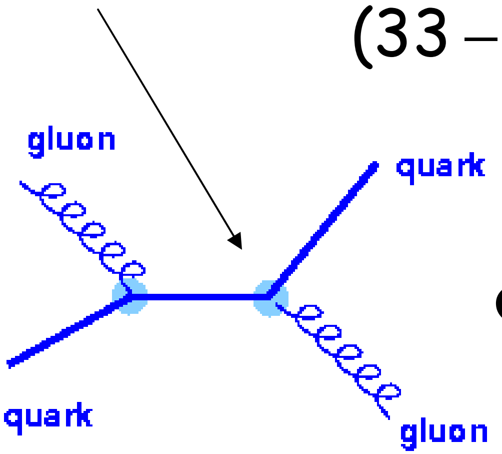
  - Test of the SM and phenomenological models in its own right
- QCD is indeed the ‘strong force’

  - i.e. large cross sections for background towards searches beyond the Standard Model

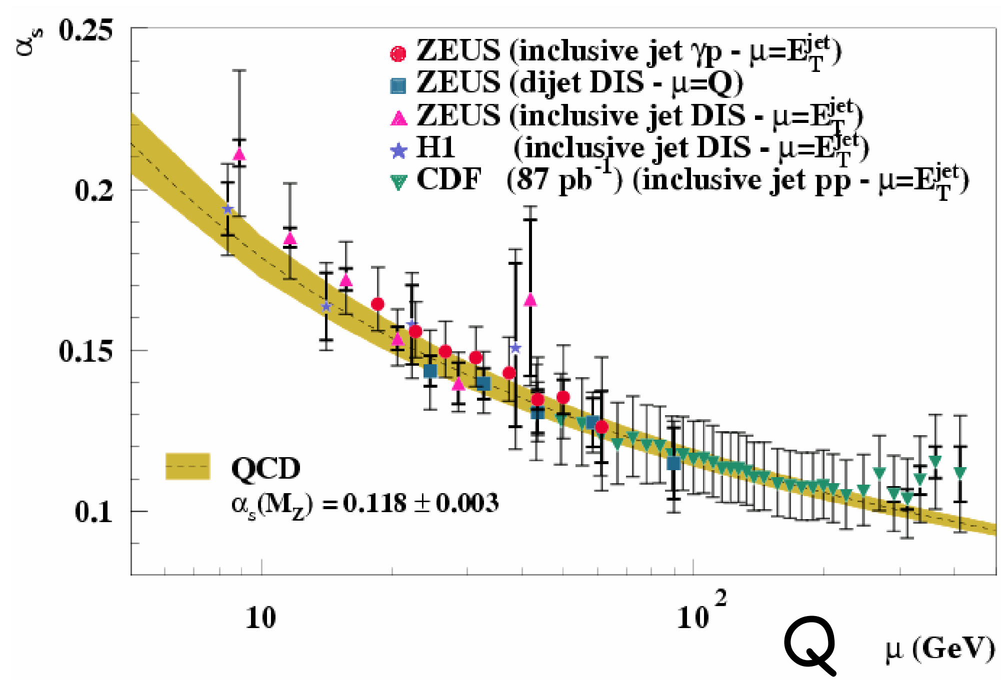


QCD : Asymptotic Freedom & Confinement

$$\alpha_s(Q^2) = \frac{12\pi}{(33-2n_f)\ln\frac{Q^2}{\Lambda^2_{QCD}}}$$



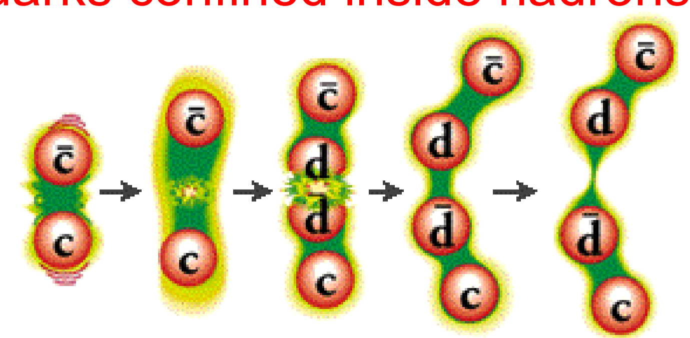
$$\hat{\sigma}_{qg\to qg}$$



At high Q (short distances) perturbation theory can be used to compute partonic cross sections

At low Q (large distances) pQCD breaks down (and we rely on phenomenological models)

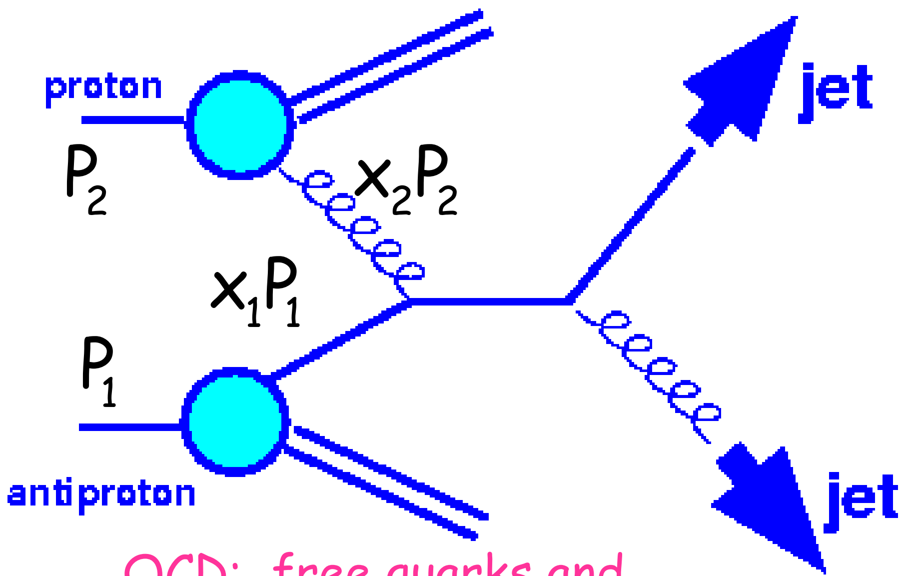
Quarks confined inside hadrons



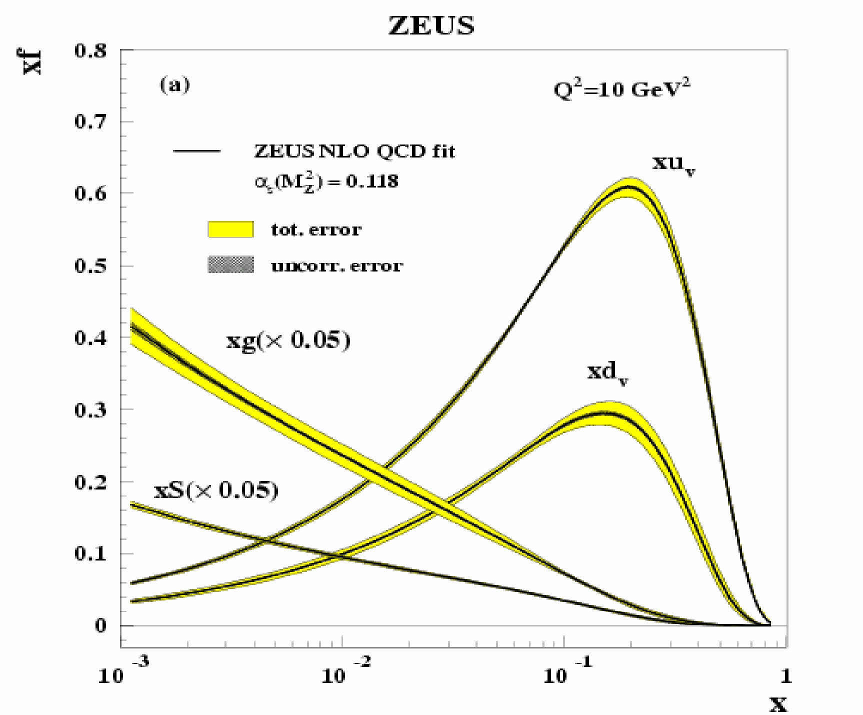
String model for hadronization

QCD Factorization

$$\sigma = \sum \int dx_1 dx_2 f_q(x_1, Q^2) f_g(x_2, Q^2) \hat{\sigma}_{qg \to qg}$$



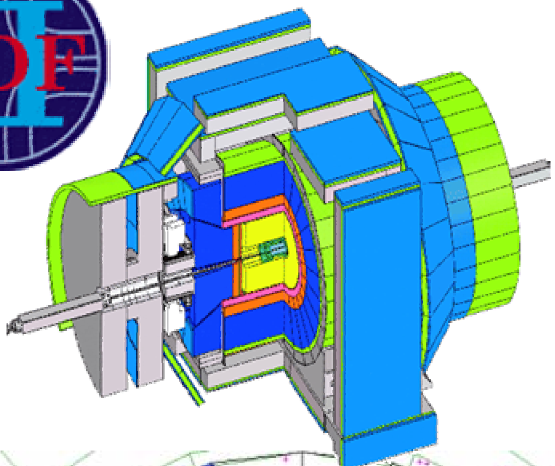
QCD: free quarks and gluons are not allowed…

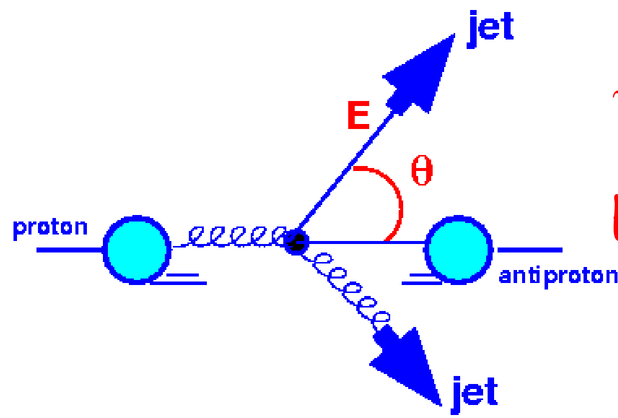


$\hat{\sigma}_{qg \to qg}$ Partonic cross section: calculated to a given order in pQCD

$f_q(x_1, Q^2)$ PDFs of parton inside the proton: needs experimental input (universal → can be used to compute different processes)

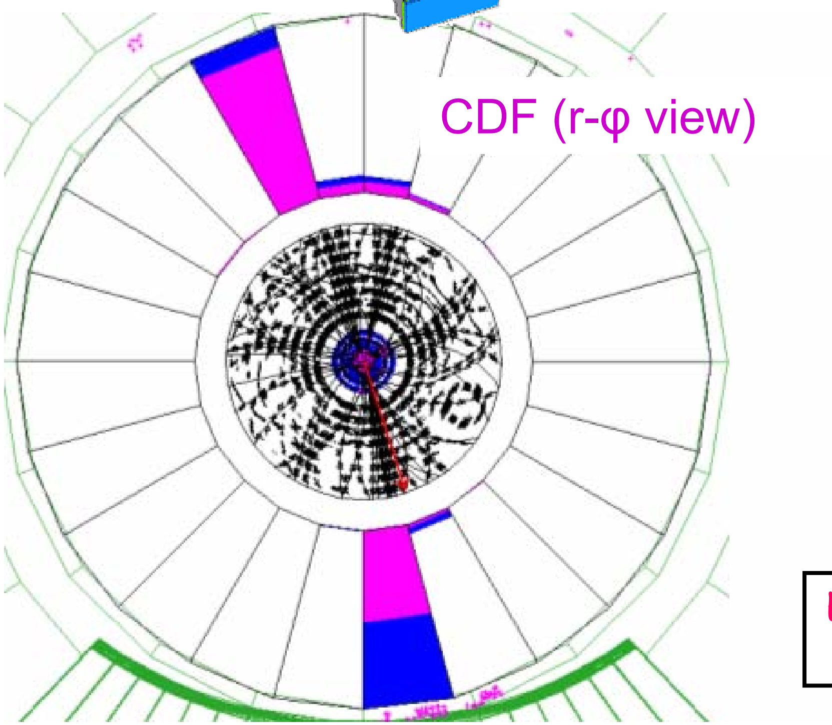
Dijet Event in CDF Detector



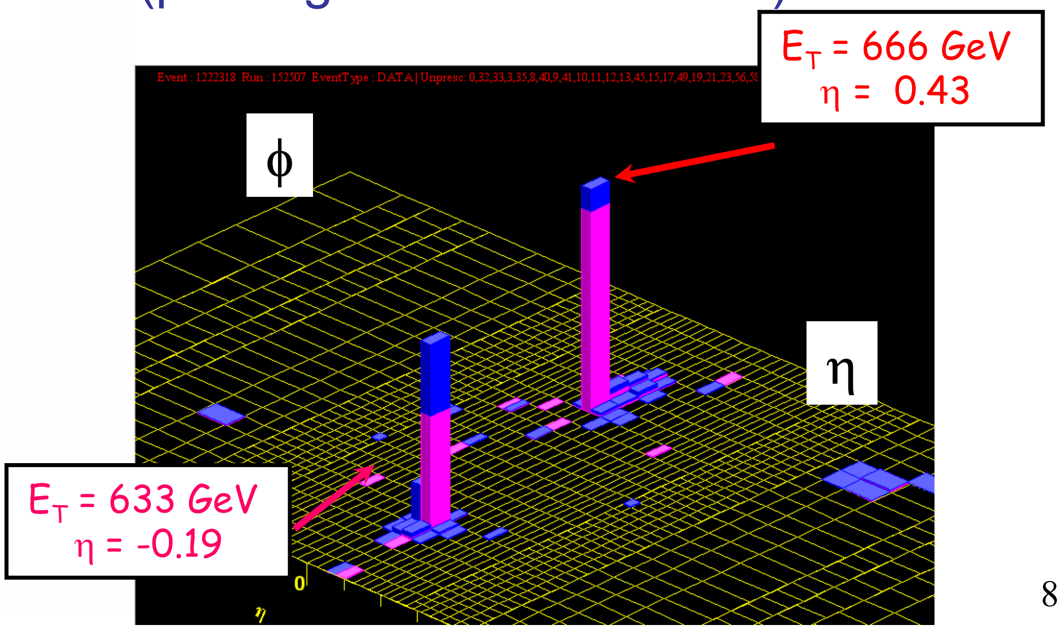


$$\eta = -\ln(\tan\frac{\theta}{2})$$

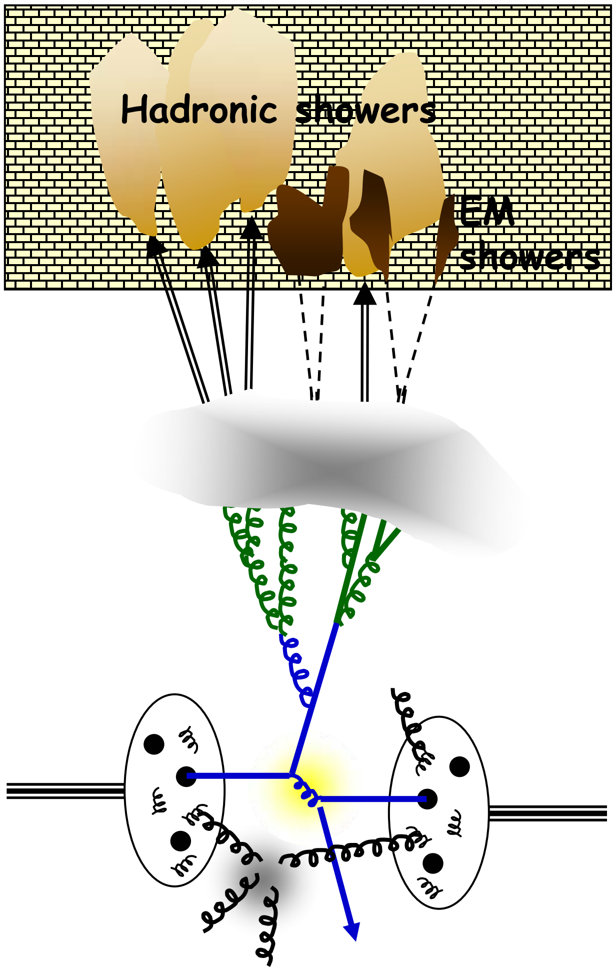
$$E_T = E\sin\theta$$



Dijet Mass = 1.36 TeV
(probing distance ~10^{-19} m)



What do we really measure?



- Calorimeter Jets:
  - Cluster calorimeter towers to jets by a jet algorithm
  - Correct for detector resolution and efficiency
  - Correct for "pile-up" – extra minimum bias events
- Hadron Jets:
  - Cluster (stable) particles in a jet algorithm using MC – correct data for difference of MC particle jet to MC calorimeter jet
- Parton Jets:
  - Correct particle level jets for for fragmentation effects
  - Correct for particles from the 'Underlying Event' (soft initial and final state gluon radiation and beam remnant interactions)

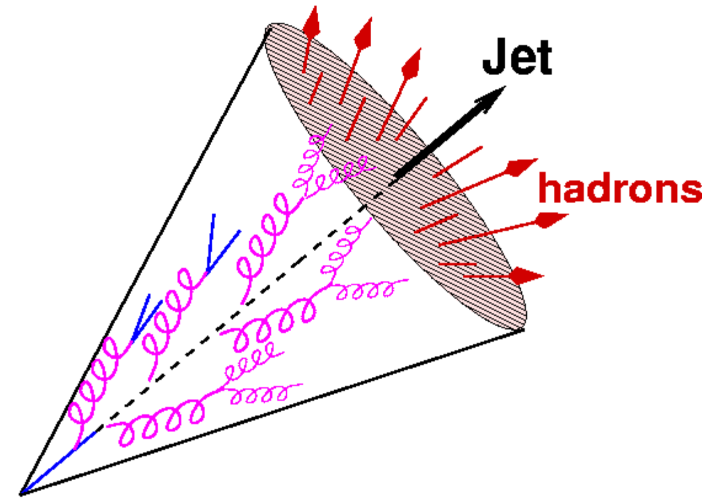
Meas'ment = PDF + pQCD ME + pQCD Approximation + UE + Had + Algo

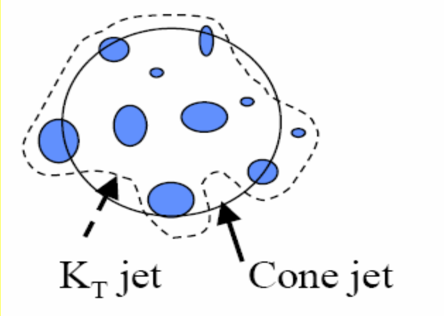
Jet Algorithms

Jets are collimated sprays of hadrons originating from the hard scattering

Appropriate jet search algorithms are necessary to define/study hard physics and compare with theory

Different algorithms correspond to different observables and give different results!





K_T

Cluster particle/towers

Based on their relative p_T

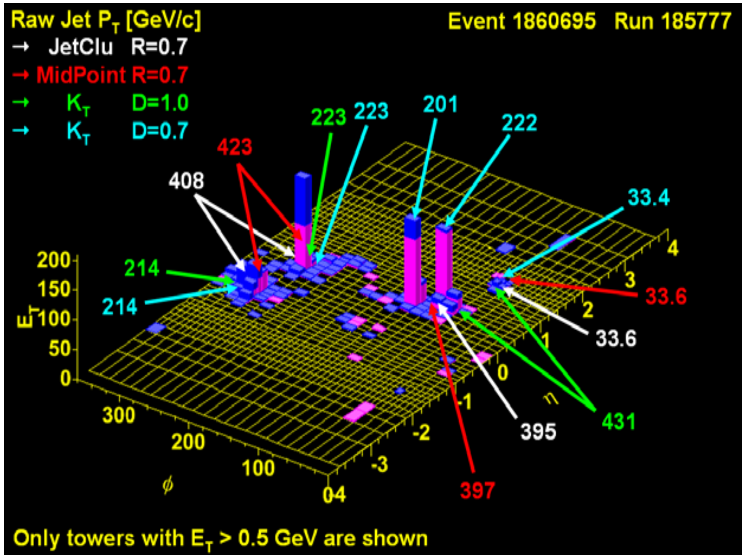
Infrared and coll. safe

No merging/spitting

MidPoint (cone)

Cluster particle/towers

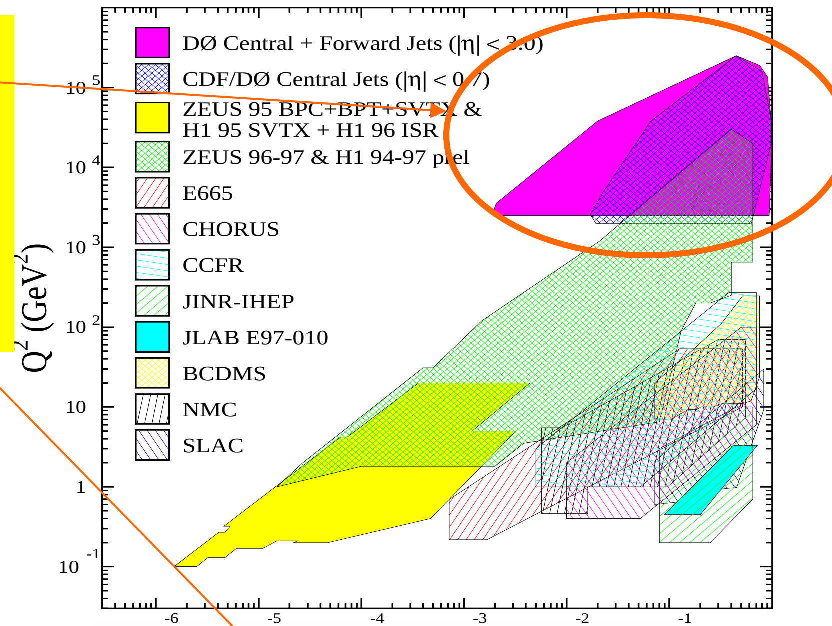
Based on their proximity in the y-ϕ plane

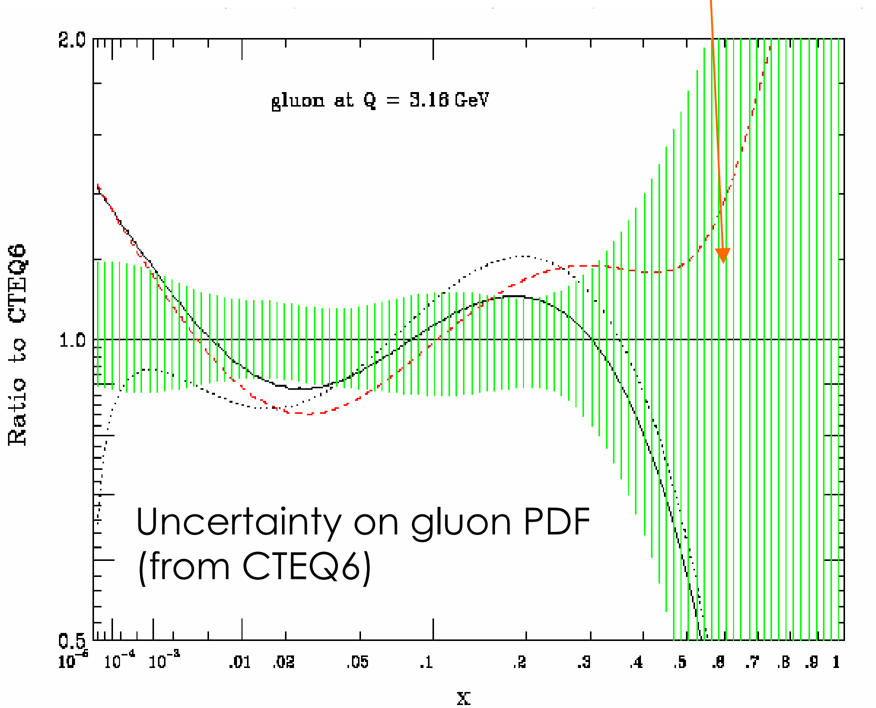


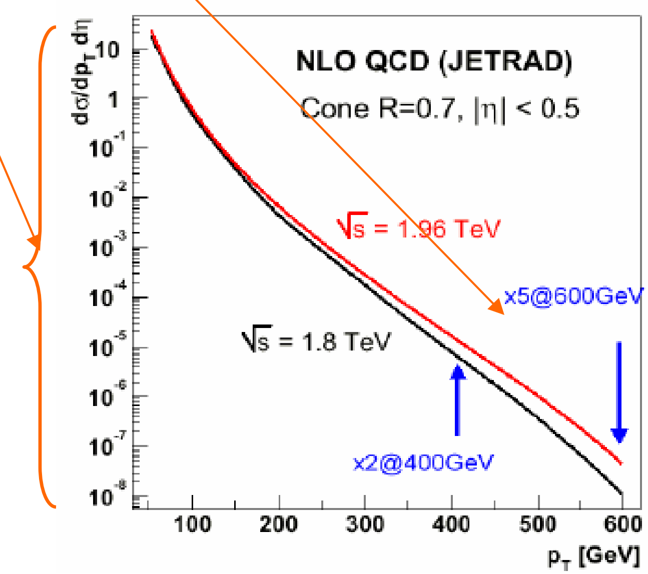
Inclusive Jet Production

Inclusive Jet Production

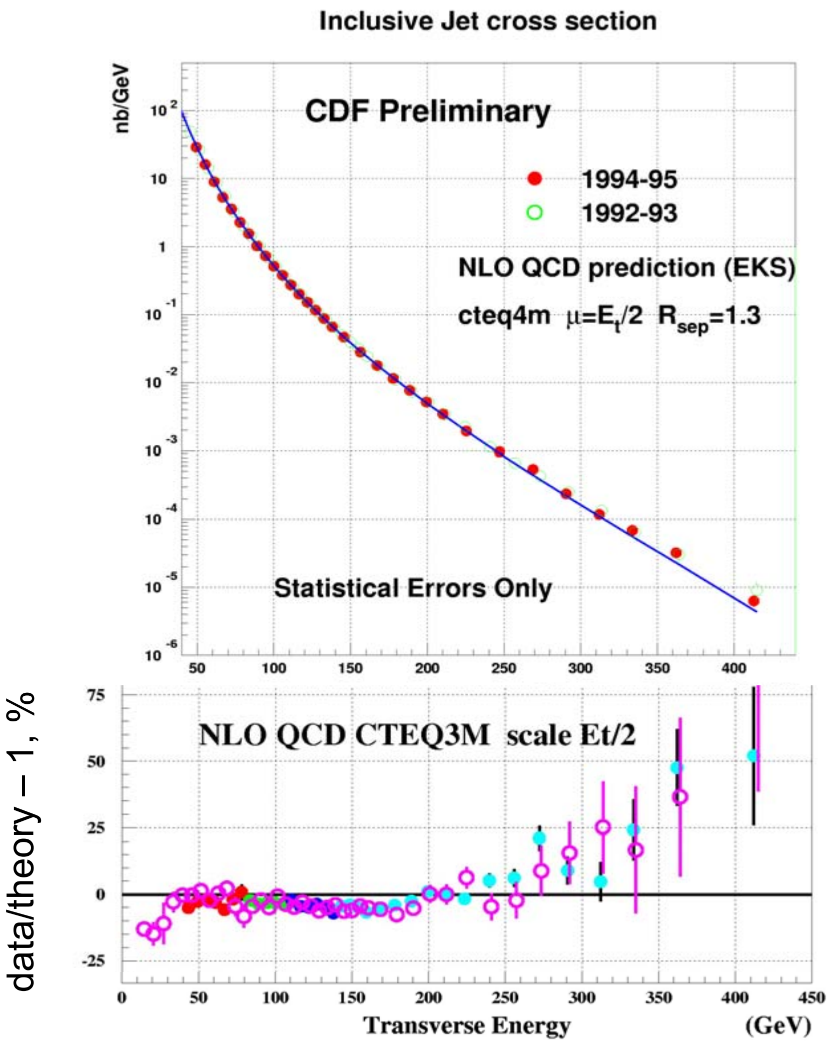
- Probes physics at small distances ≈10^{-19}m
- Higher reach in pT due to increased √s
- Test pQCD over more than 9 decades in σ
- Sensitive to PDF (gluon @ high-x)







Inclusive Jet Production: Run I legacy

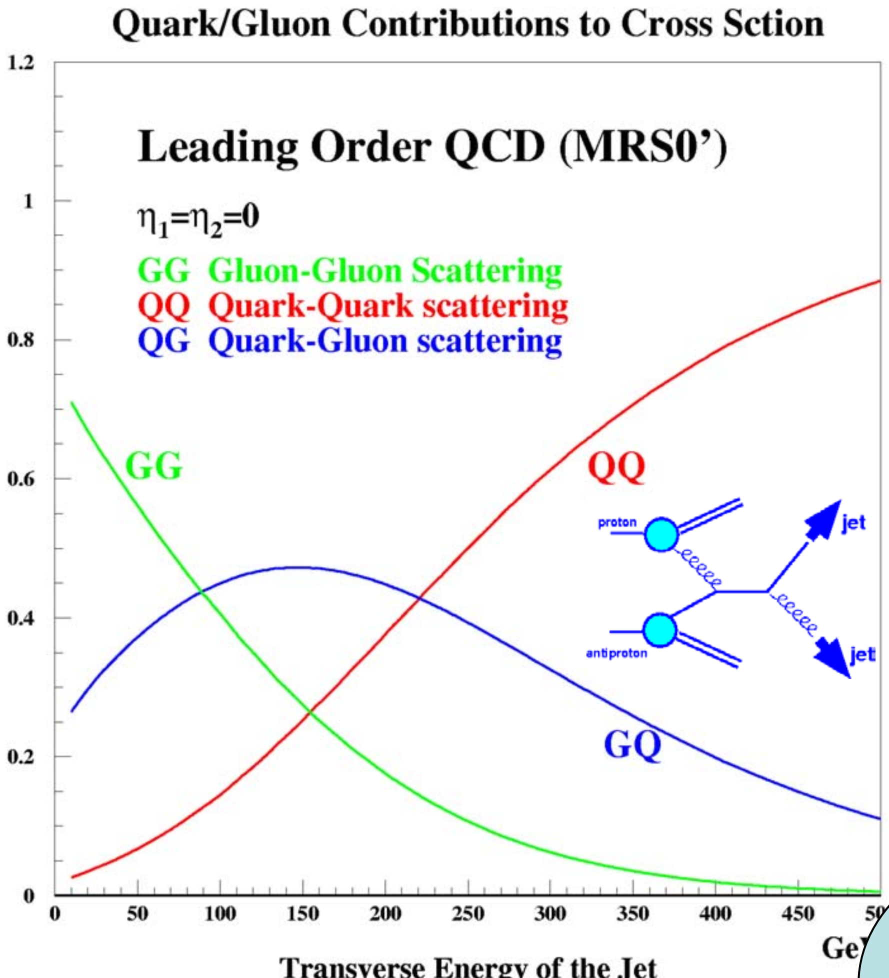


- Run I
  - Cone jet finding algorithm
  - Apparent excess at high pT, but within the overall systematic errors
  - Is it New Physics or parton distribution function ?

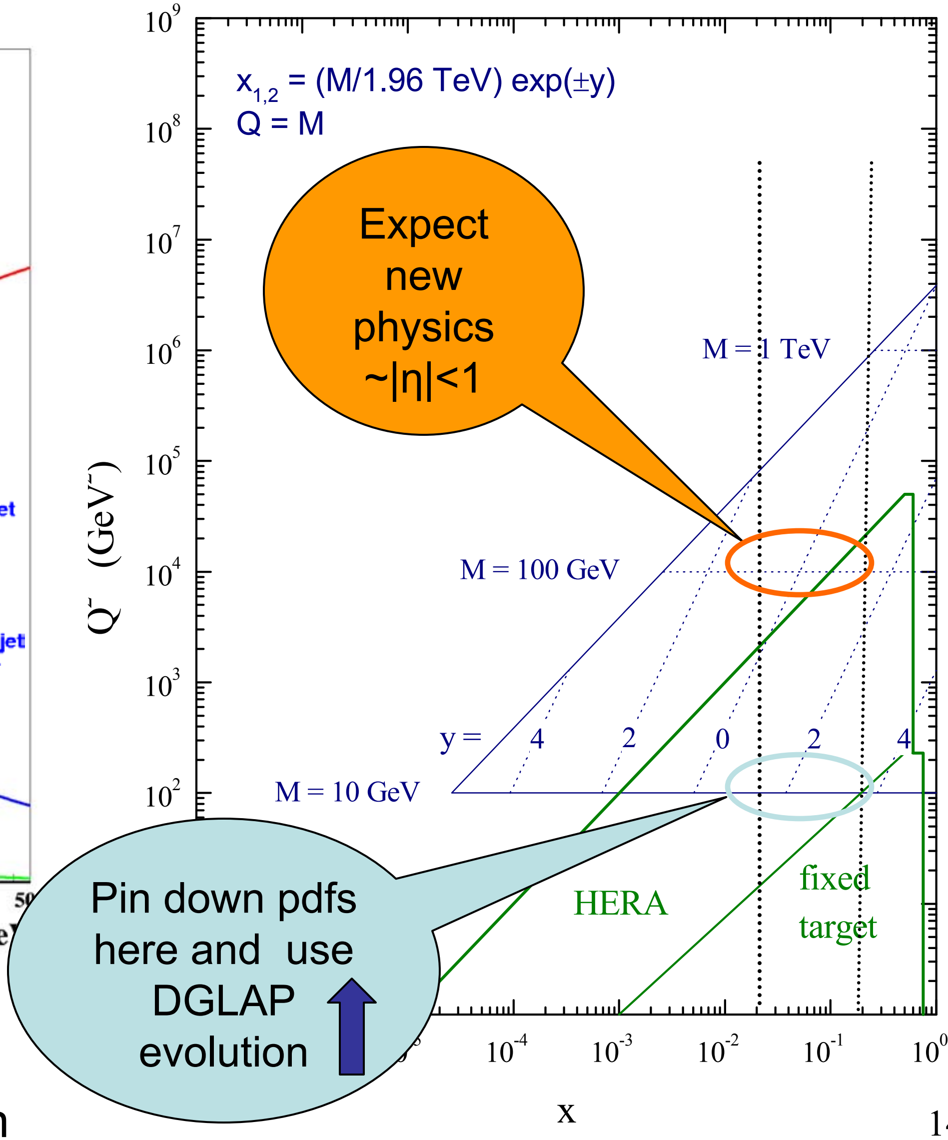
- Between Run I and Run II
  - Machinery for improved jet finding algorithms:
    - MidPoint Cone Algorithm
    - kT Algorithm

  PDFs are further tuned

Inclusive Jet Production



Tevatron parton kinematics

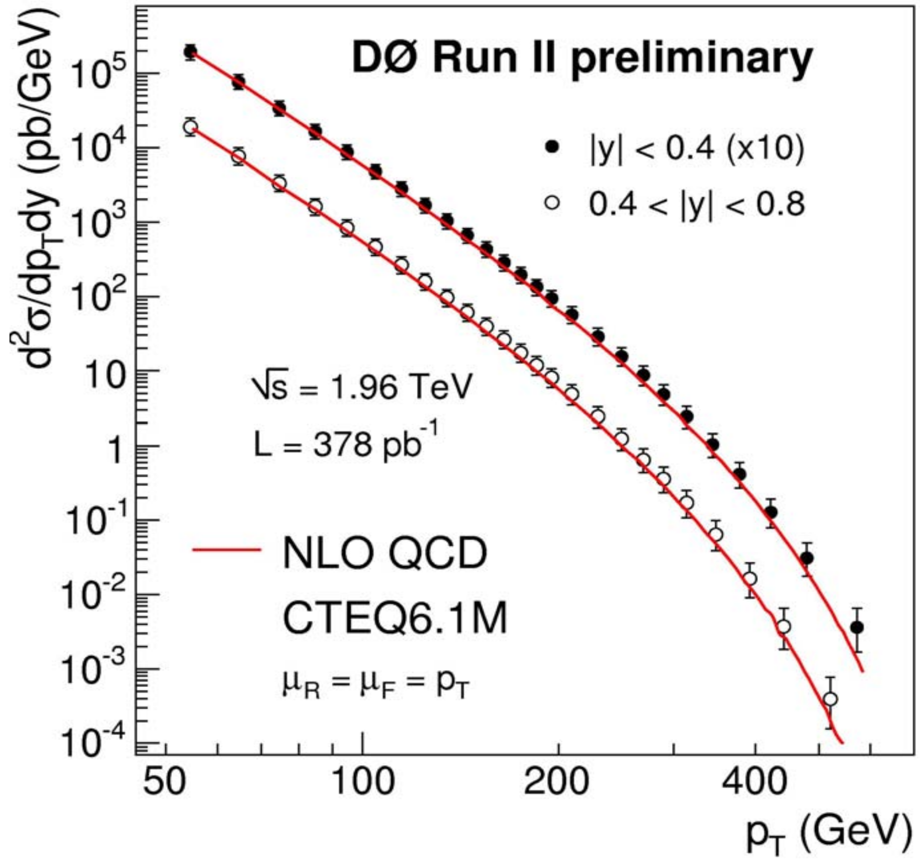


- Gluon contribution significant
- use forward jets to pin down pdfs versus new physics at higher Q^2 in central region

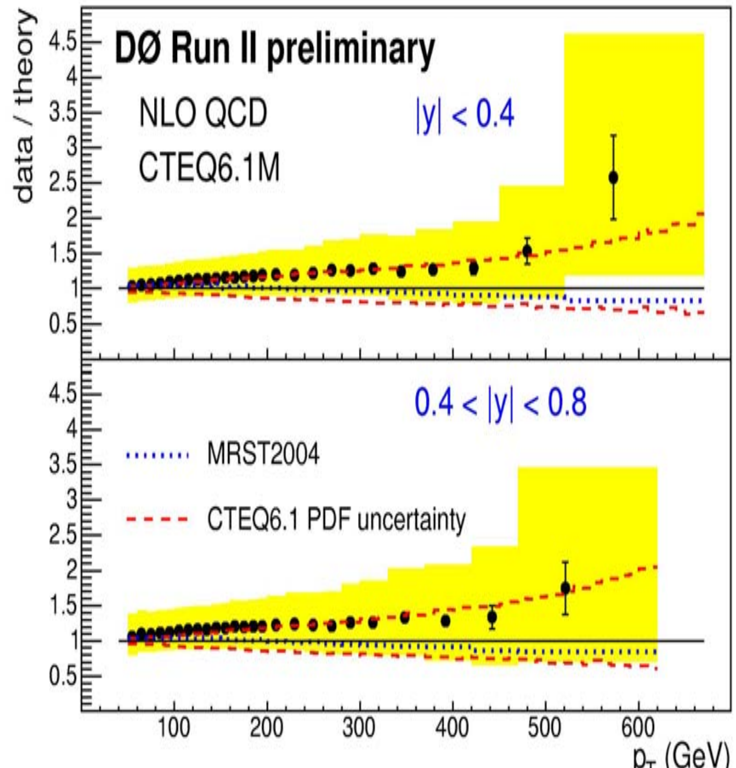
Inclusive Jet Cross Section-D0
(MidPoint algorithm R=0.7)

- 2 regions in rapidity explored
  $|y^{jet}| < 0.4$
  $0.4 < |y^{jet}| < 0.8$

L = 380 pb^{-1}



Jet energy scale uncertainty
➔ dominant error

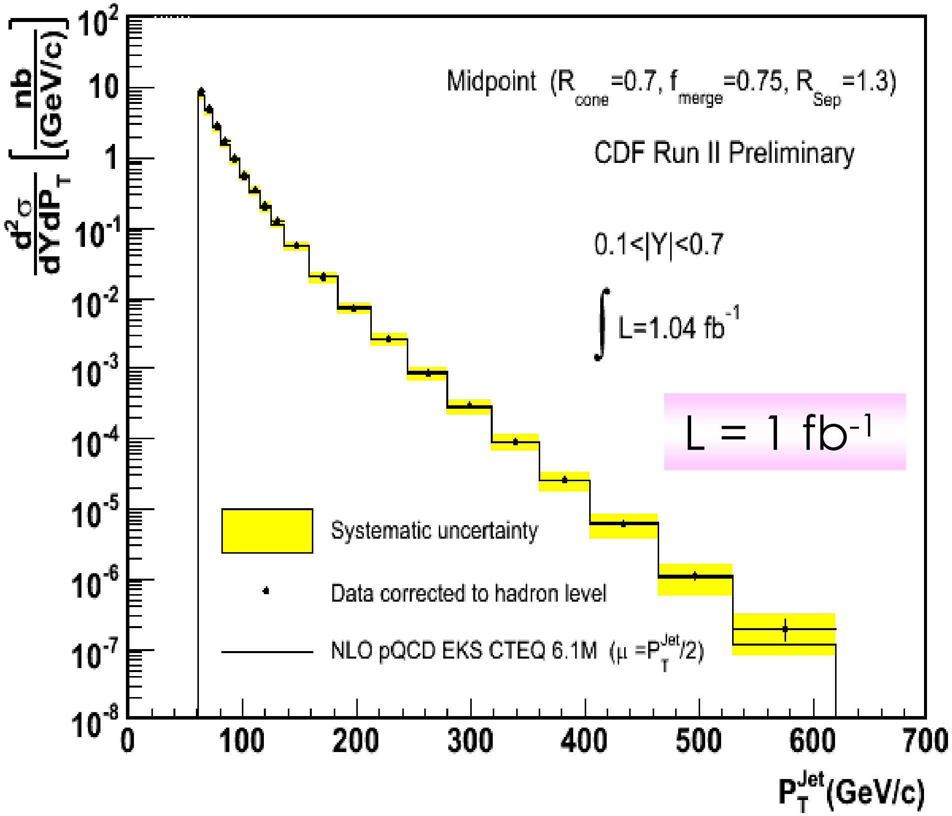


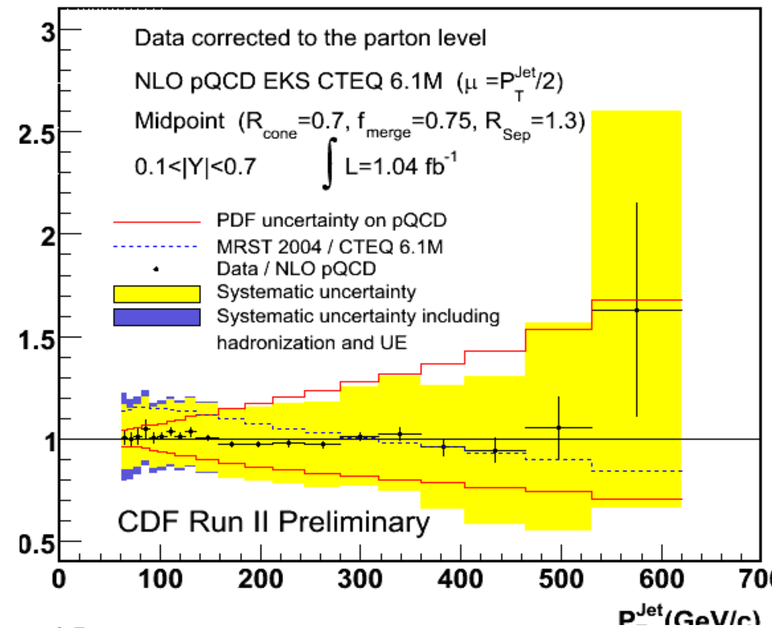
Good agreement with NLO prediction (direct comparison of hadron to parton level i.e. neglect fragmentation and UE)

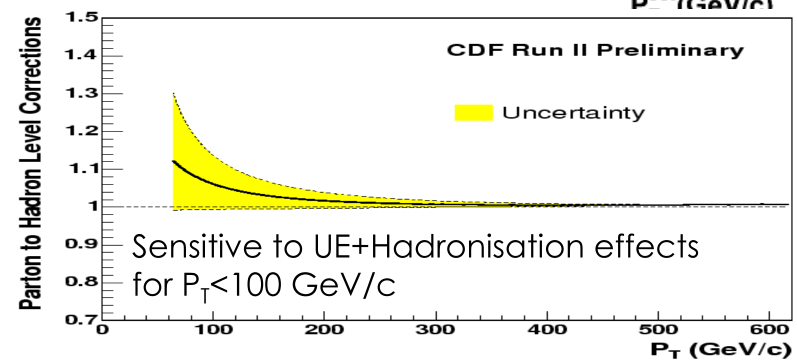
Inclusive Jet Cross Section

- MidPoint algorithm R = 0.7
- Central jets: $0.1<|y^{jet}|< 0.7$
- More than 8 orders of magnitude covered

- Data dominated by Jet Energy Scale (JES) uncertainties (2-3%)
- Thy uncertainty dominated by high x gluon PDF

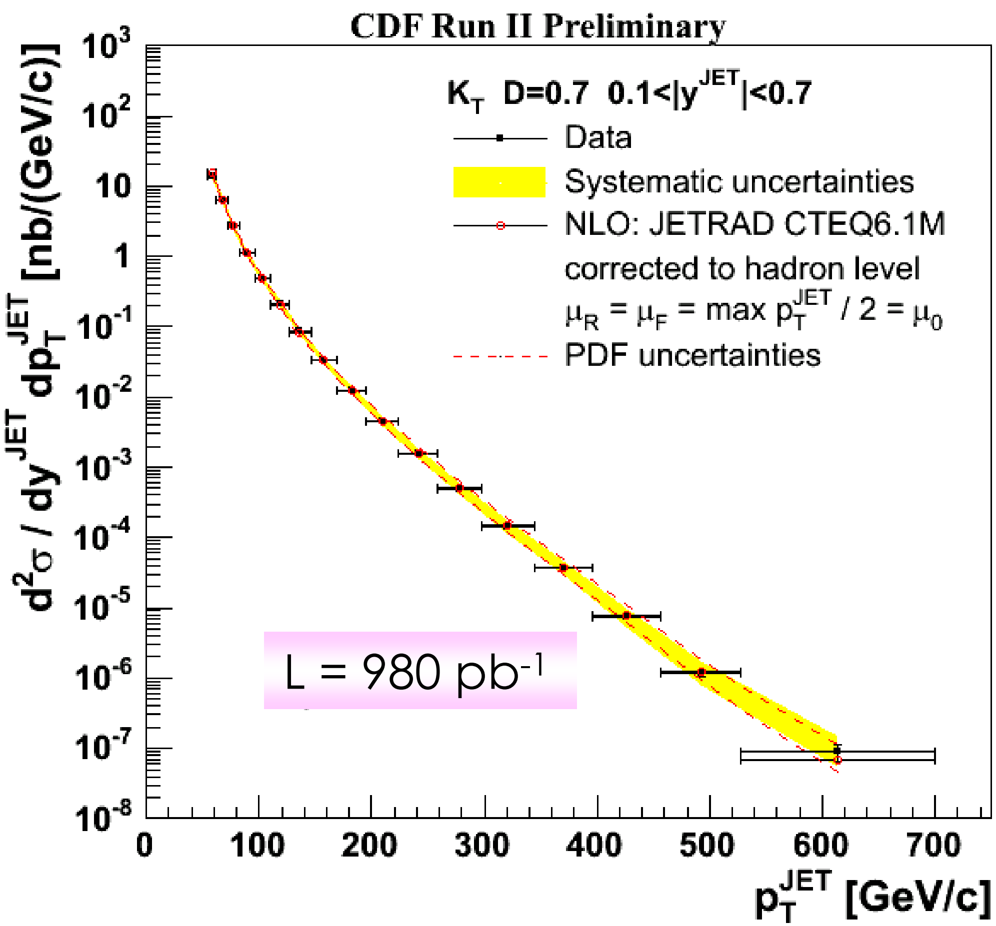


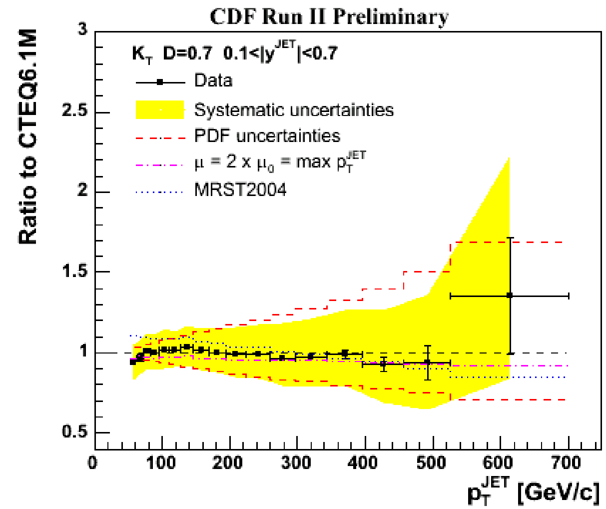


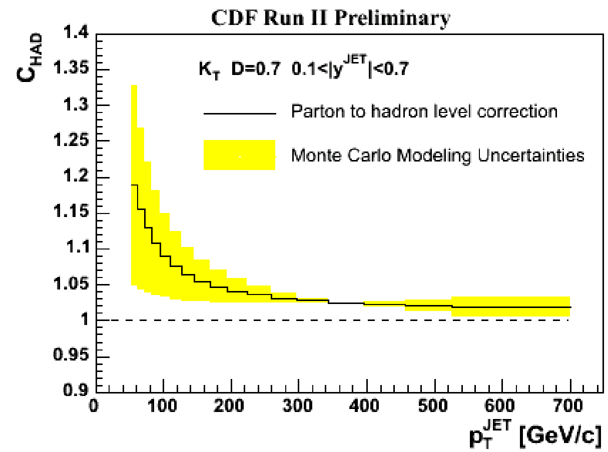


Good agreement with NLO predictions
(direct comparison of hadron to parton level as well as data corrected to parton level)

Inclusive Jet Cross Section

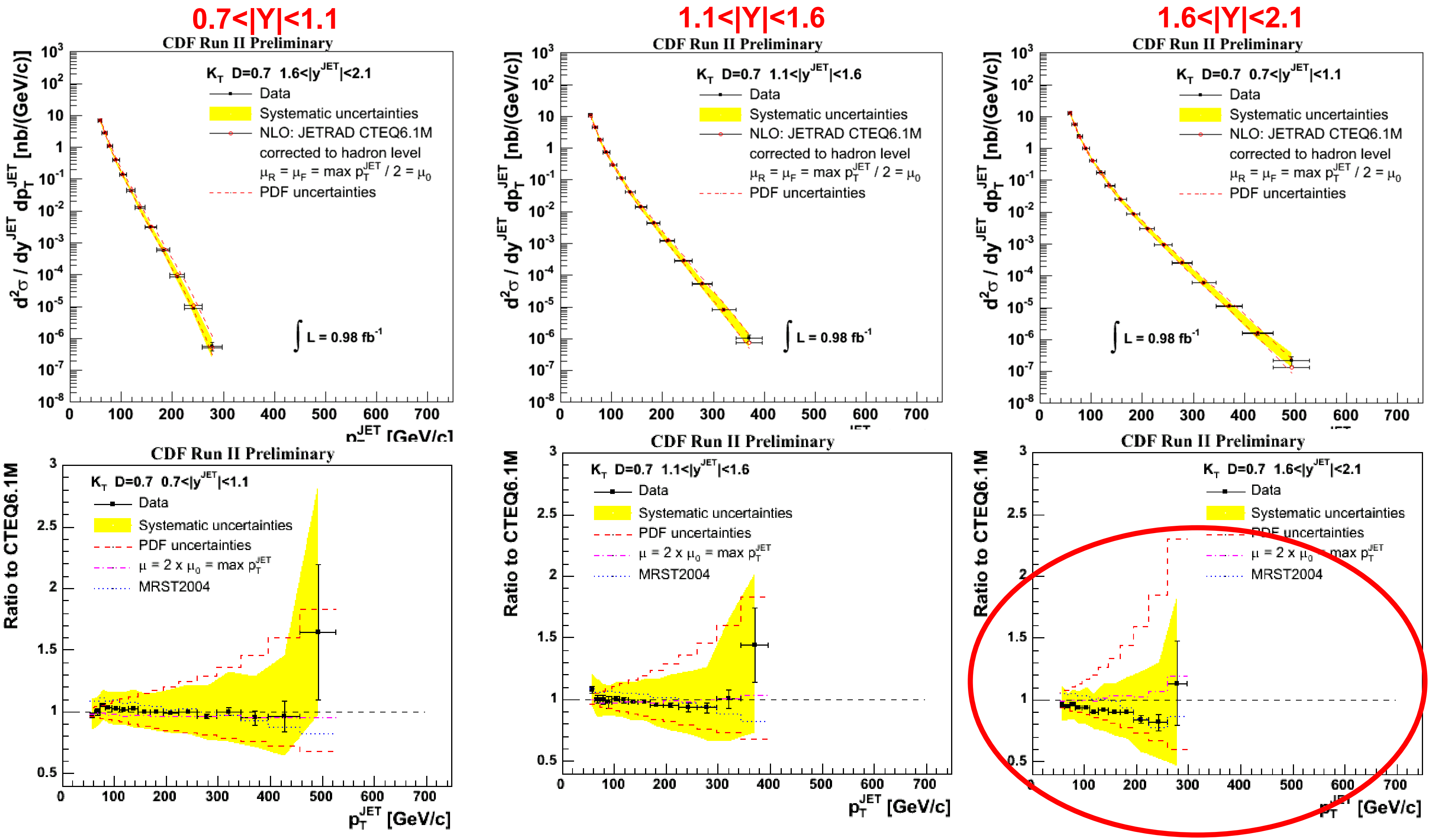






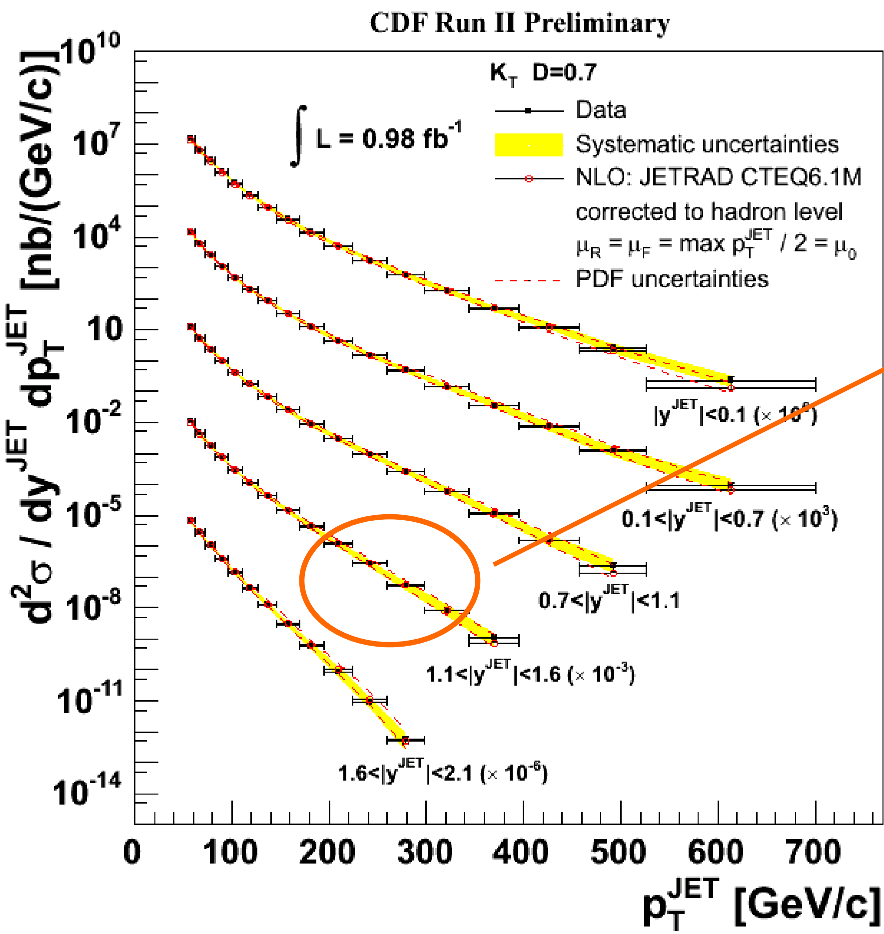
K_T algorithm performs well in hadron collisions
(i.e. with an underlying event)
Good agreement with NLO pQCD (both data and thy compared at hadron level)

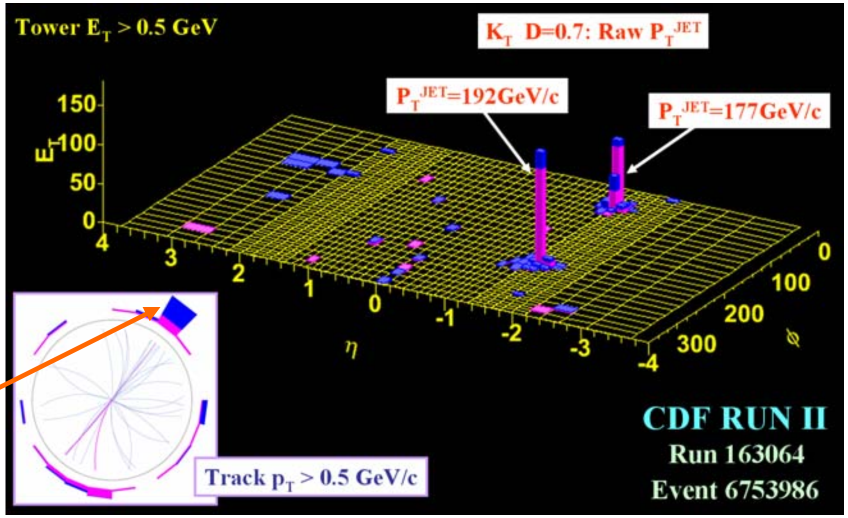
Forward jets (k_T algorithm)

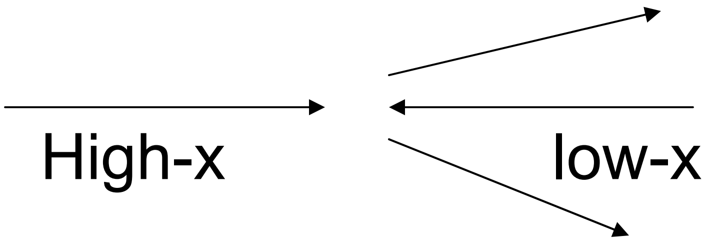


Data will further constrain high x gluon in global fits

High-x Event

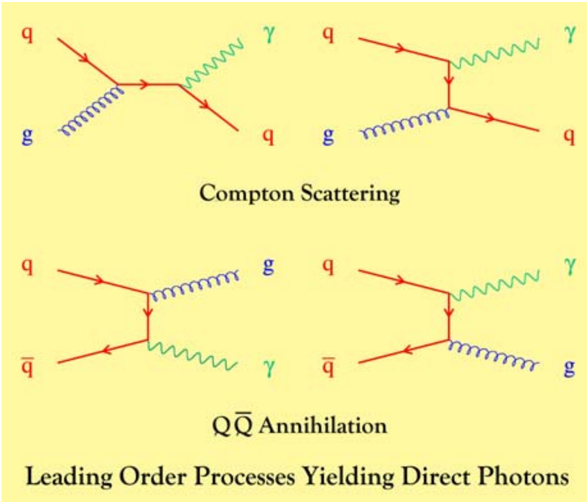


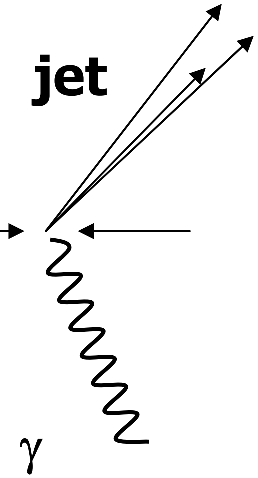


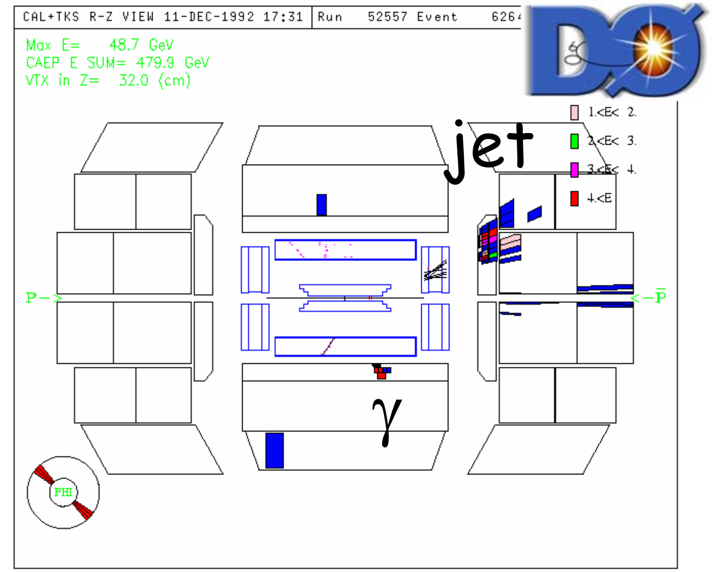


A "Rutherford type" parton backscattering

Direct Photon Production



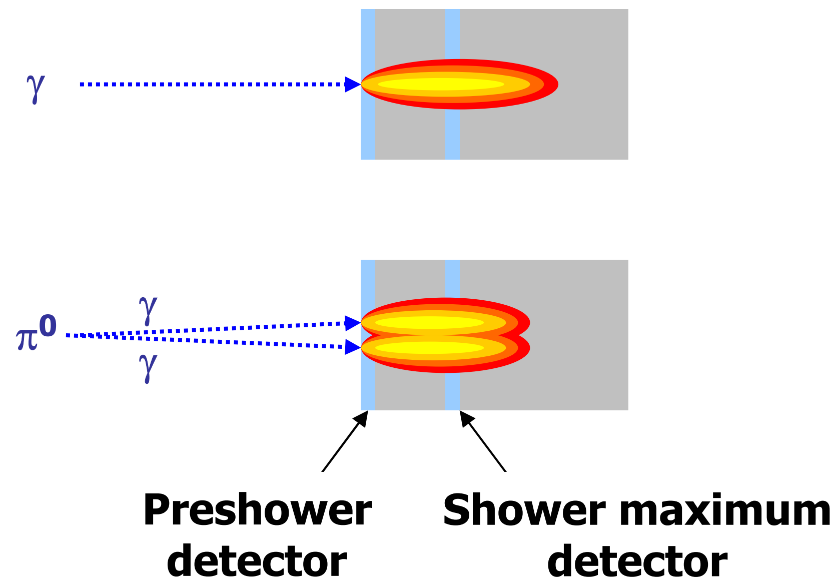




Using prompt photons one can precisely study QCD dynamics:

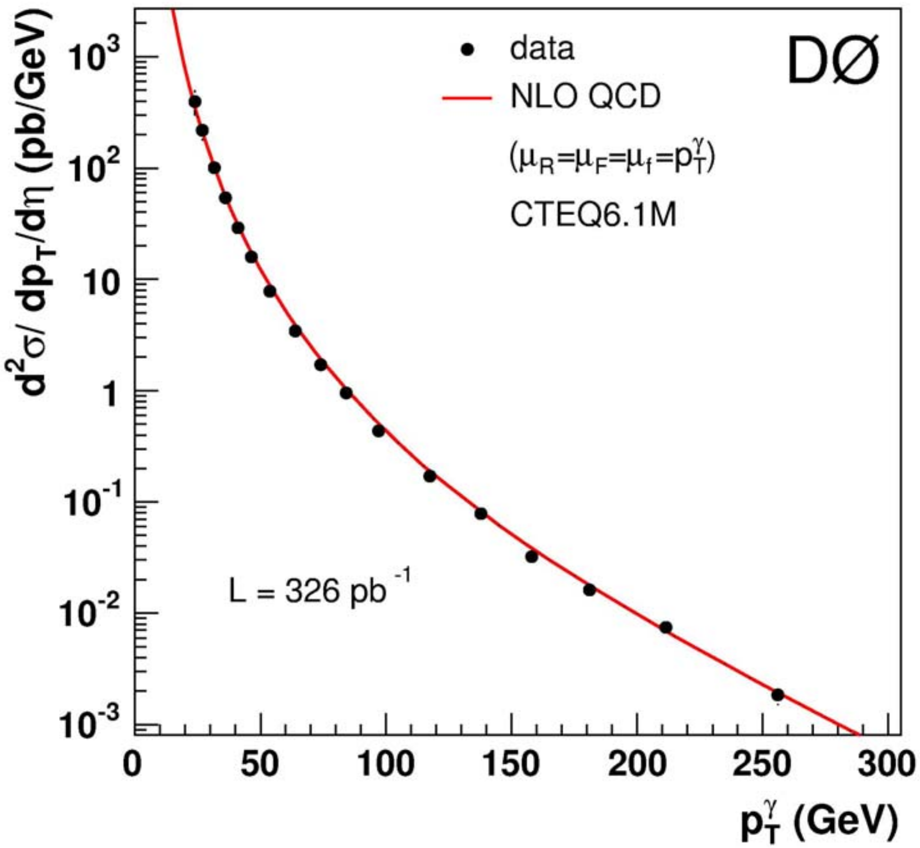
- Well known coupling to quarks
- Give access to lower Pt
- Clean: no need to define "jets"
- constrain of gluon PDF

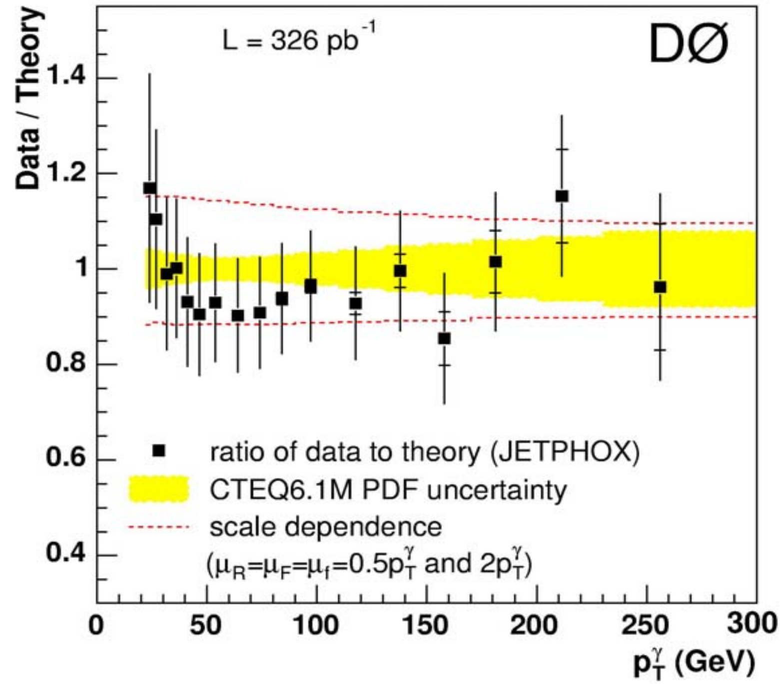
Experimentally difficult because of large background from π^0 decays



Inclusive γ cross section

- Highest $p_T(\gamma)$ is 442 GeV/c
  - 3 events above 300 GeV/c not displayed



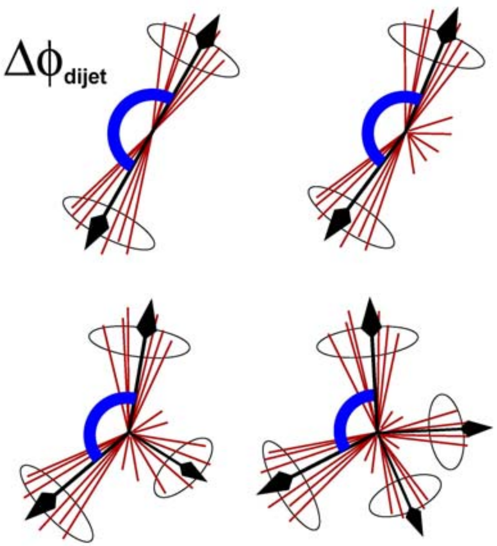


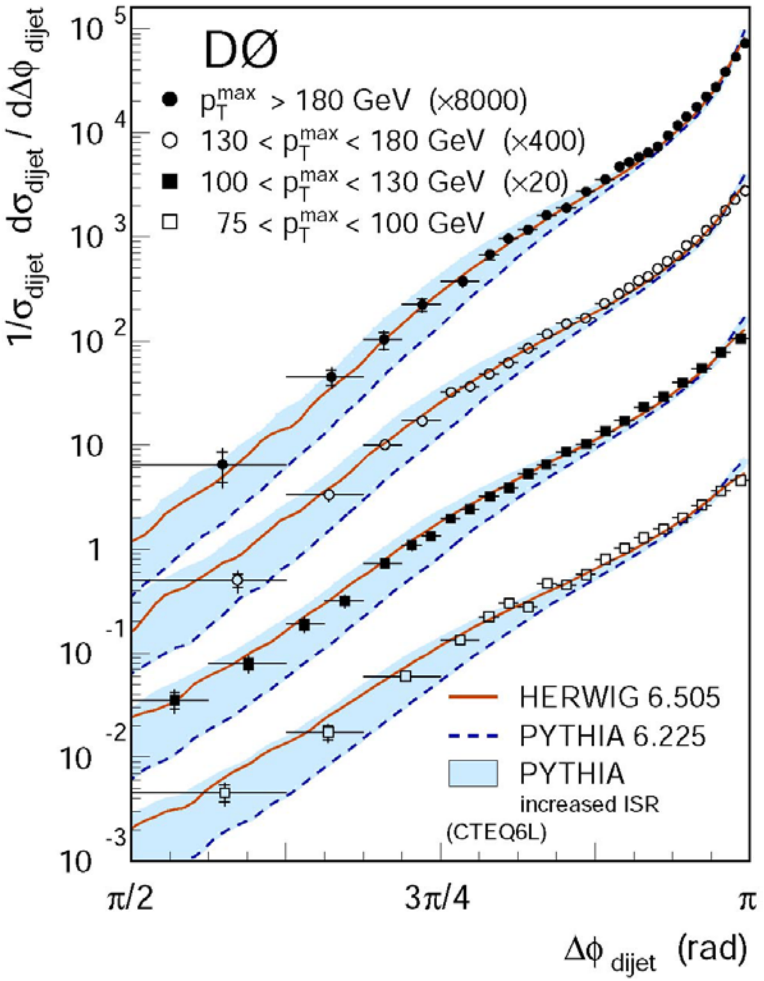
Good agreement with pQCD NLO

- Errors ~20%
- Very promising at ~ fb^{-1} luminosities to constrain gluon PDF at high x

Jet-Jet Correlations

Jet#1-Jet#2 Δφ Distribution



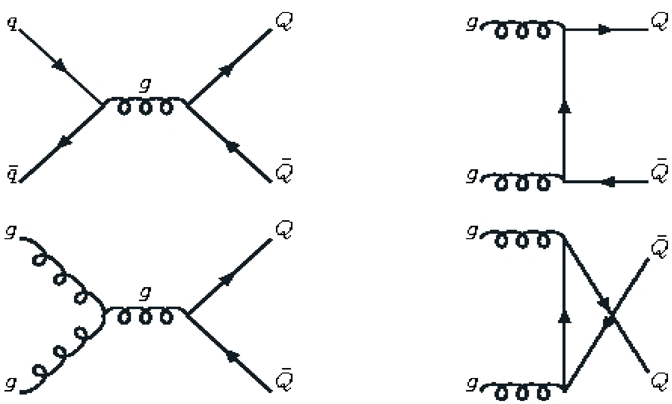


- MidPoint Cone Algorithm (R = 0.7, f_{merge} = 0.5)
- L = 150 pb^{-1} (Phys. Rev. Lett. 94 221801 (2005))
- Data/HERWIG agreement good.
- Data/PYTHIA(TuneA) agreement good

Inclusive b-jet Production

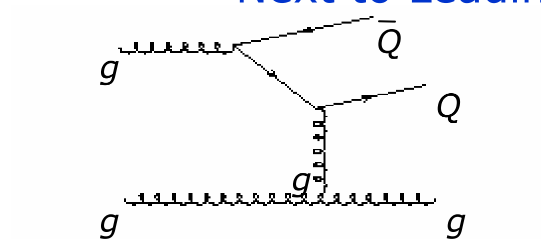
B-quark production in hadron collisions

Leading Order

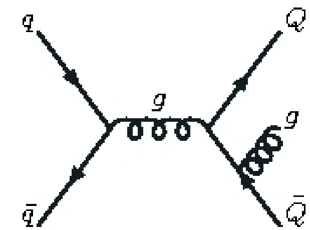


Flavor creation

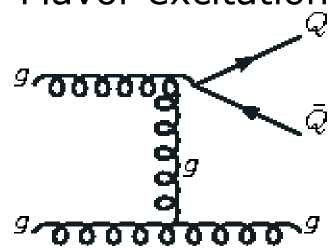
Next to Leading Order



Flavor excitation



other radiative corrections..



Gluon splitting

Experimental inputs are B-Hadrons or b-jets rather than b-quark

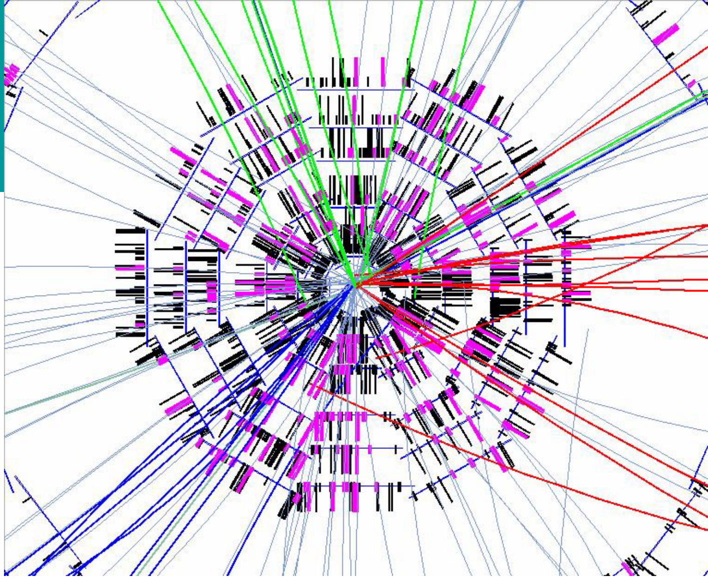
Proton structure

$$\frac{d\sigma\left(p\bar{p} \to BX\right)}{d\,p_T(B)} = \underbrace{\frac{d\sigma\left(q\bar{q}/gg/qg \to bX\right)}{d\,p_T(b)}}_{\text{NLO QCD}} \otimes F^{p\bar{p}} \otimes D^{b\to B}$$

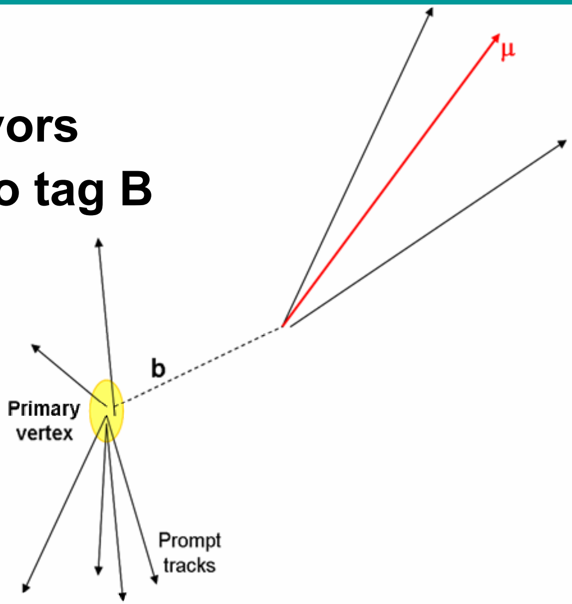
Fragmentation

=> Another stringent test of NLO QCD

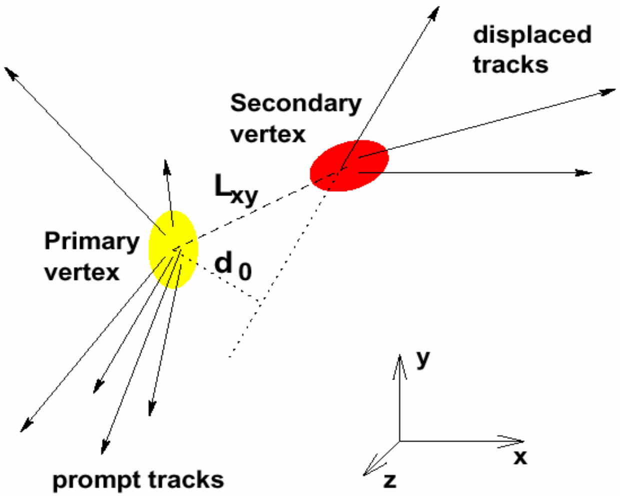
Tagging Bs



- B hadrons are massive
  - decay into lighter flavors
  - use decay products to tag B
  - 'Soft Lepton Tag'

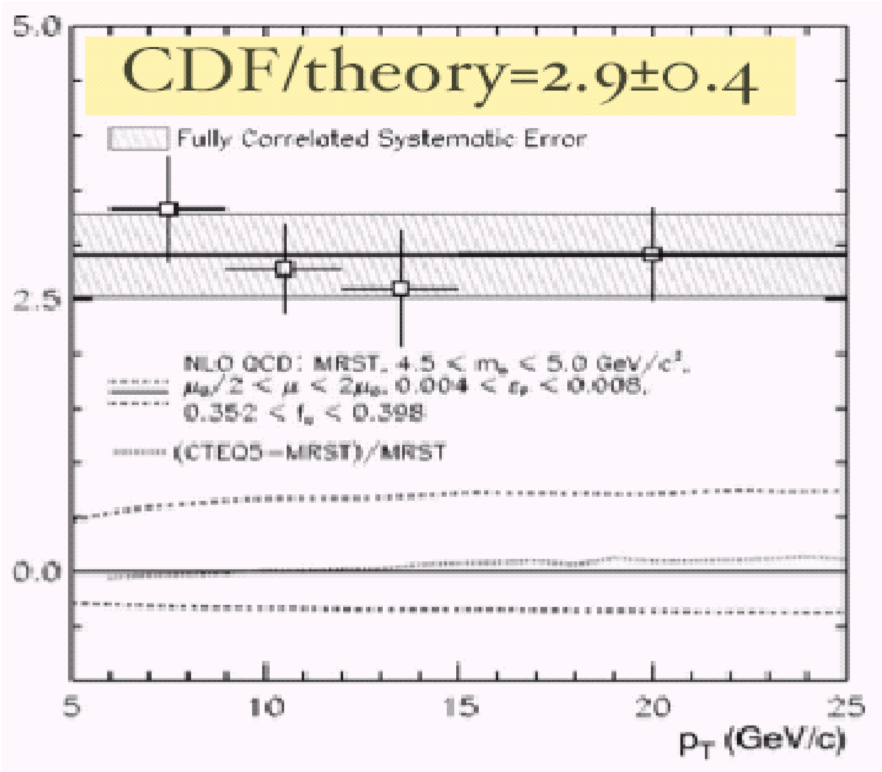


- B hadrons are long lived
  - $c\tau \sim 460\ \mu m$
  - give rise to secondary vertices
  - tracks from secondary vertex have non-vanishing impact parameter d_0 at primary vertex
  - 'Secondary Vertex Tag' & 'Jet probability'



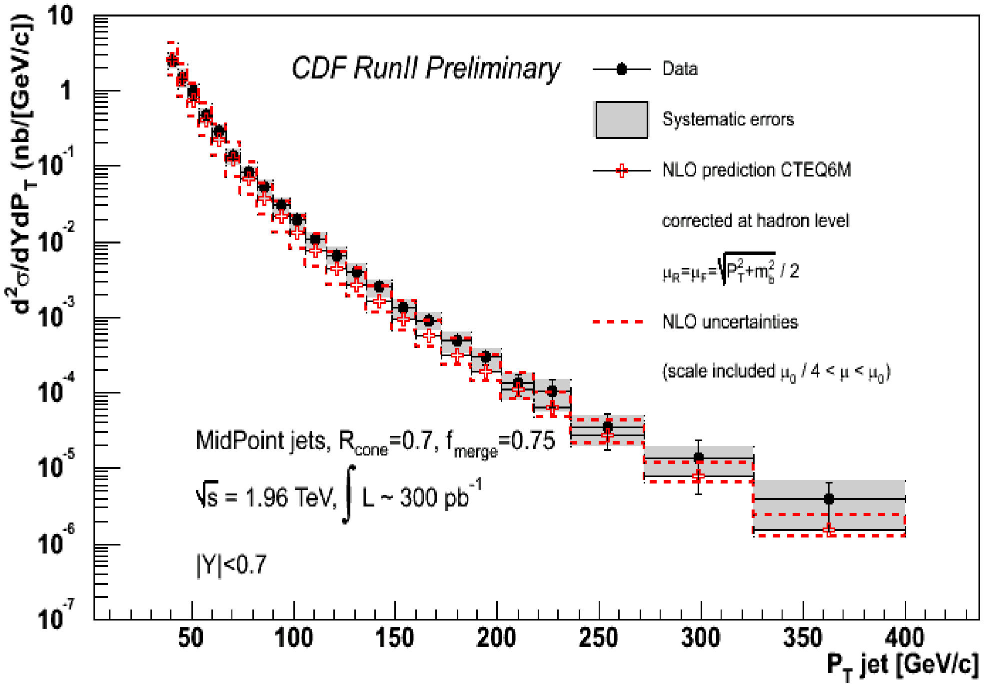
Run I Legacy

- In Run I, a factor 3 discrepancy was reported between theory predictions and experimental data by both CDF and DØ in b-hadron cross sections

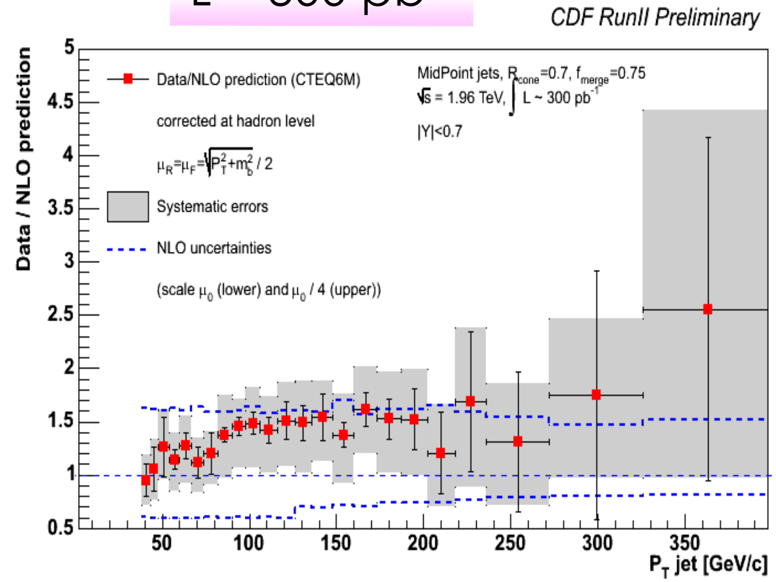


High P_T b-jet cross section

- Beauty production → Test of pQCD
- MidPoint jets: R = 0.7, $|y^{jet}| < 0.7$
- Reconstruct secondary vertex from B hadron decays (b-tagging)
- Shape of secondary vertex mass used to extract b-fraction from data



L = 300 pb^{-1}



- More than 6 orders of magnitude covered
- Data systematic uncertainties dominated by Jet Energy Scale and b-fraction uncertainties
- Main uncertainties on NLO due μ_R/μ_F scales

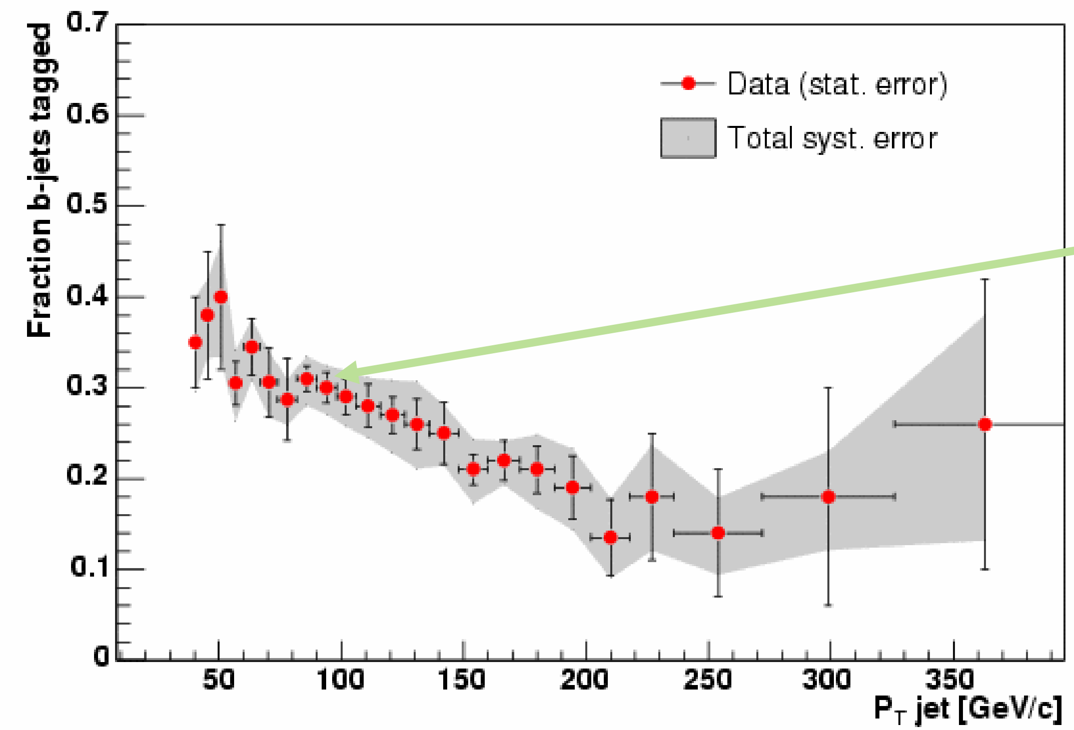
Agreement with pQCD NLO within systematic uncertainties
→ Sensitive to high order effect (NNLO)

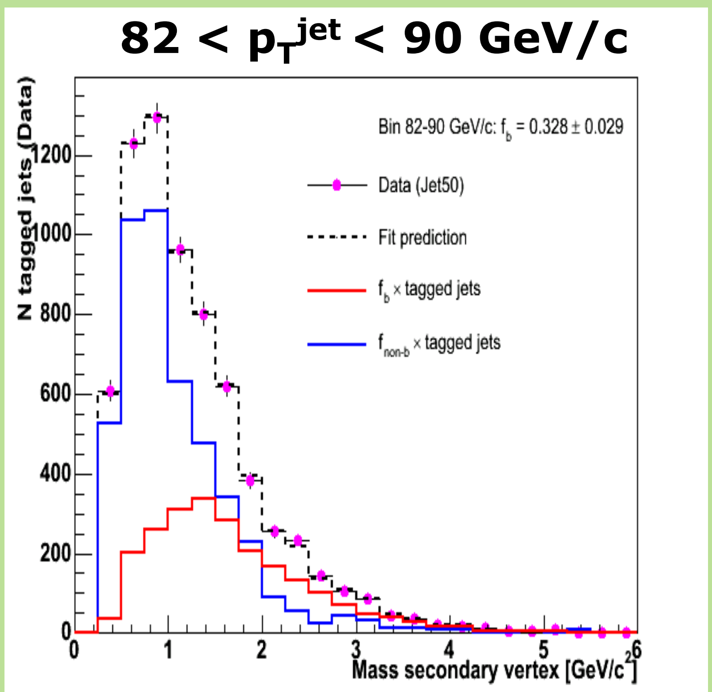
Fraction of tagged b-jets

Extract fraction of b-tagged jets from data using shape of mass of secondary vertex as discriminating quantity

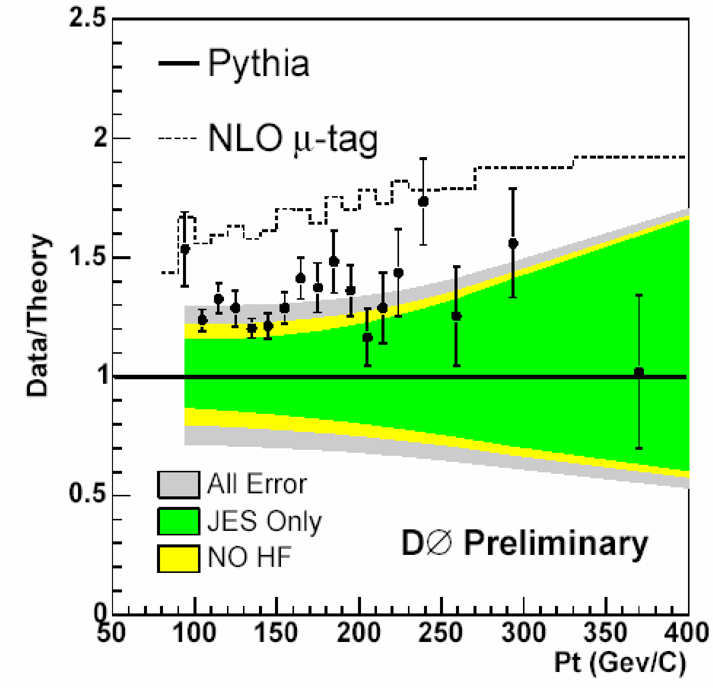
→bin-by-bin as a function of jet p_T

→2 component fit:b and non-b templates
(Monte Carlo PYTHIA)

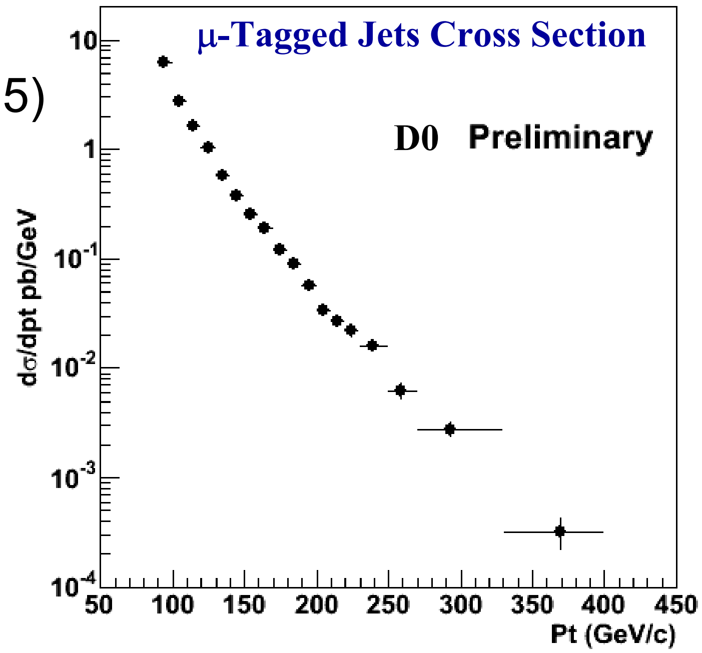




μ-Tagged Jets Correlations



- MidPoint Cone Algorithm (R = 0.5)
- Require muon in R = 0.5.
- L = 300 pb^{-1}
- $|y_{jet}| < 0.5$
- $P_T(m) > 5$ GeV/c



- Searching for muons in jets enhances the heavy flavor content.
- Data/PYTHIA ~ 1.3 flat.

The b-bbar DiJet Cross-Section

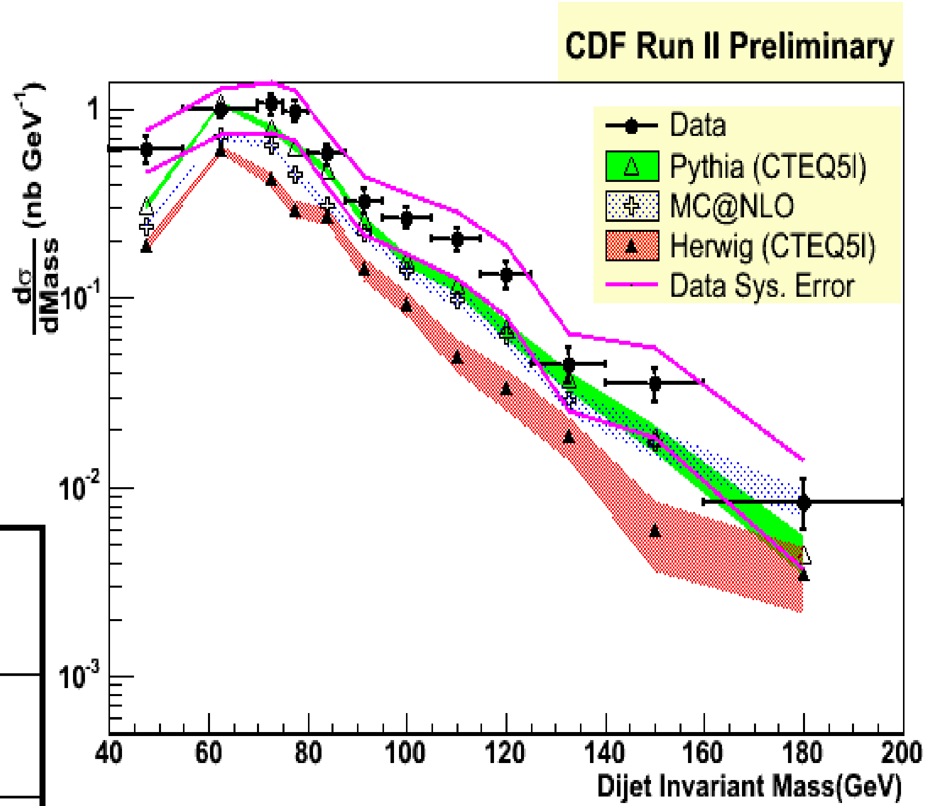
- E_T(b-jet#1) > 30 GeV, E_T(b-jet#2) > 20 GeV, $|\eta$(b-jets)$| < 1.2$.

Preliminary CDF Results:

$$\sigma_{bb} = 34.5 \pm 1.8 \pm 10.5 \text{ nb}$$

QCD Monte-Carlo Predictions:

PYTHIA Tune A CTEQ5L	38.71 ± 0.62nb
HERWIG CTEQ5L	21.53 ± 0.66nb
MC@NLO	28.49 ± 0.58nb



- Large SystematicUncertainty:
  - Jet Energy Scale (~20%).
  - b-tagging Efficiency (~8%)
- PYTHIA vs.Data ~ 1.4 flat
  - expect due NLO corrections
  - Consistent with D0 result

The b-bbar DiJet Cross-Section

- E_T(b-jet#1) > 30 GeV, E_T(b-jet#2) > 20 GeV, $|\eta$(b-jets)$| < 1.2$.

Preliminary CDF Results:

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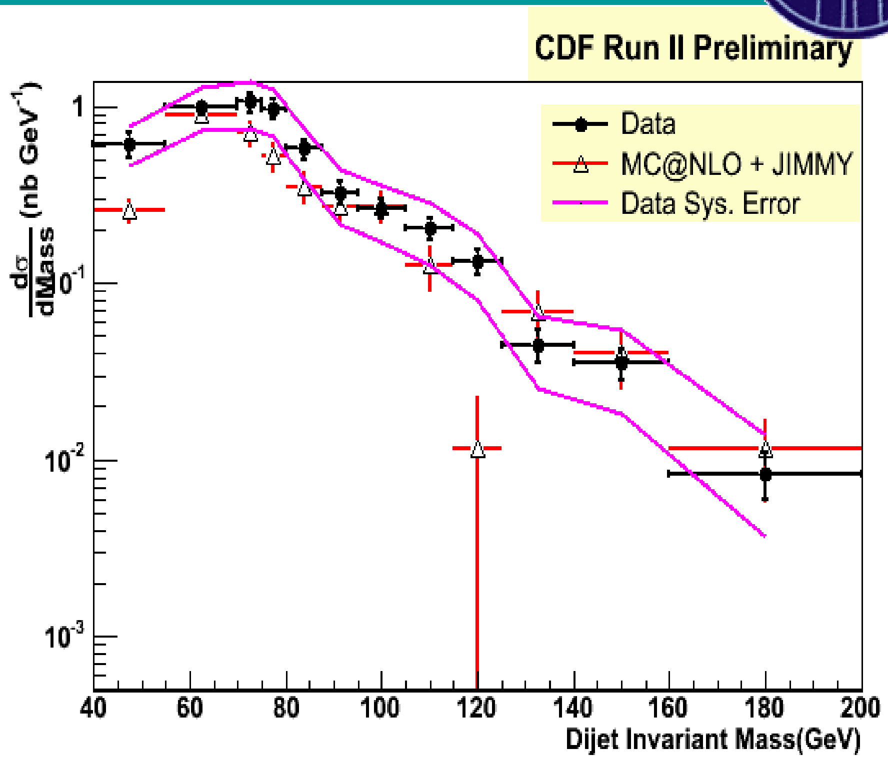
QCD Monte-Carlo Predictions:

PYTHIA Tune A CTEQ5L	38.71 ± 0.62nb
HERWIG CTEQ5L	21.53 ± 0.66nb
MC@NLO	28.49 ± 0.58nb
MC@NLO + JIMMY	35.7 ± 2.0 nb

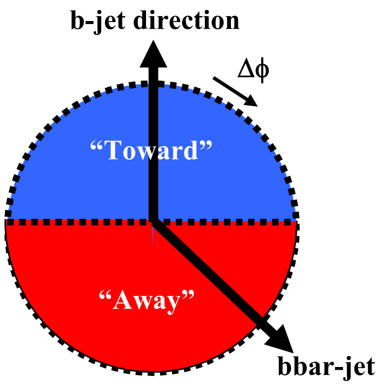


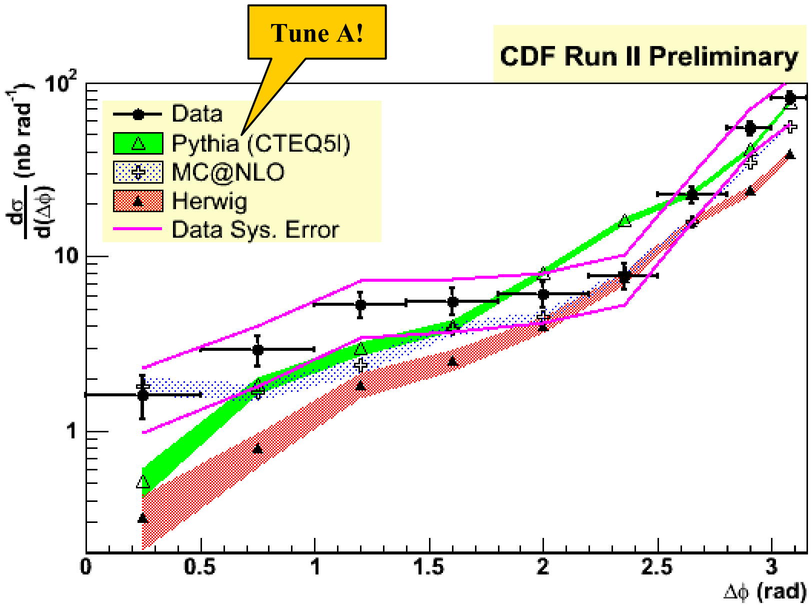
JIMMY: HERWIG + multiple parton interactions

Enhances underlying event and b-cross section

=> Better agreement of NLO calculation with data!

b-bbar DiJet Correlations

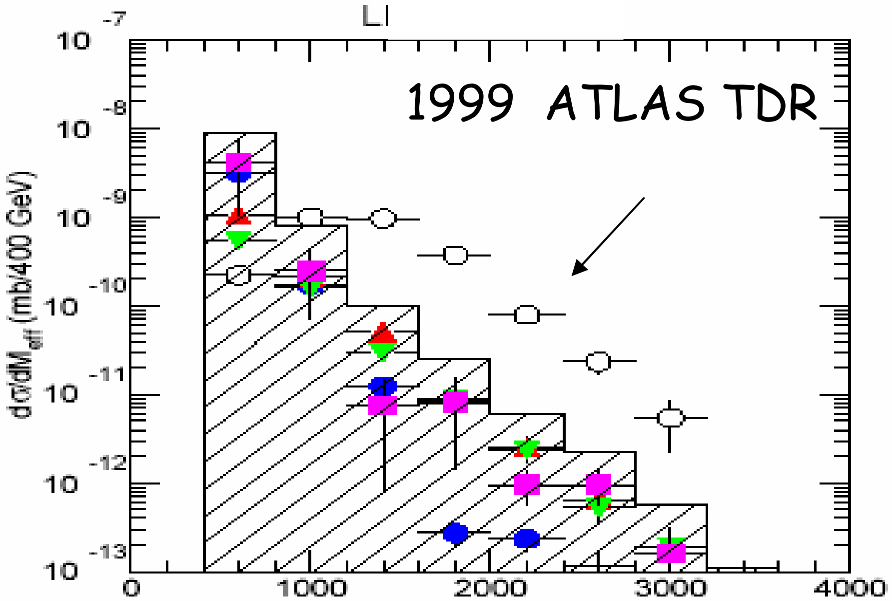




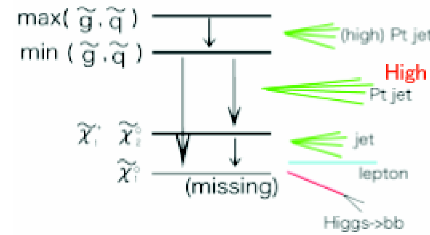
- The two b-jets are predominately "back-to-back"
  - Angular distribution sensitive to fraction of flavor creation (back to back) to gluon splitting and flavor excitation
- Pythia Tune A agrees fairly well with the correlation
  - Run 1b data was used in Pythia Tune A

Vector Boson/Jets Final States: Background to Searches

QCD and New Physics

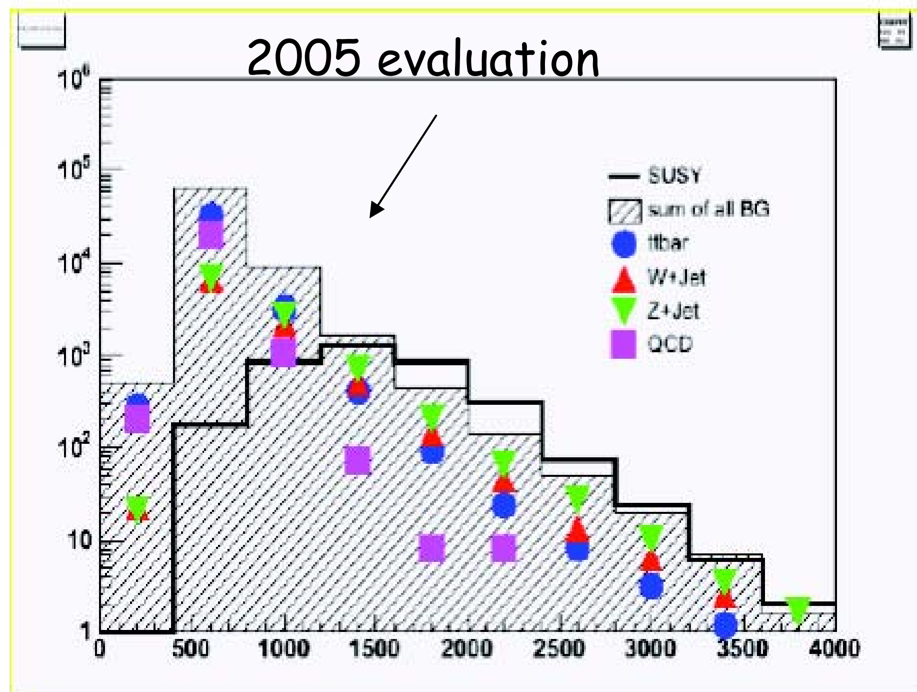


$$M_{eff} = H_T + \not{E}_T$$



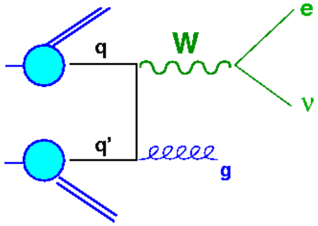
Event topologies of SUSY are:

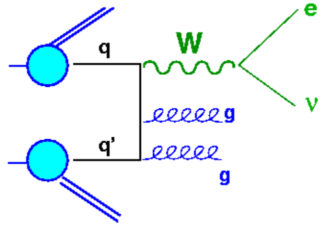
	multi	leptons
$\not{E}_T$ +	High P_T jets +	b-jets
		τ-jets



- Preliminary MC studies (1999) suggested that SUSY could be discovered via cascade decays within weeks after LHC start-up
- New W/Z+jet(s) programs (ALPGEN) predict a much harder jet Et distributions than PYTHIA+PS

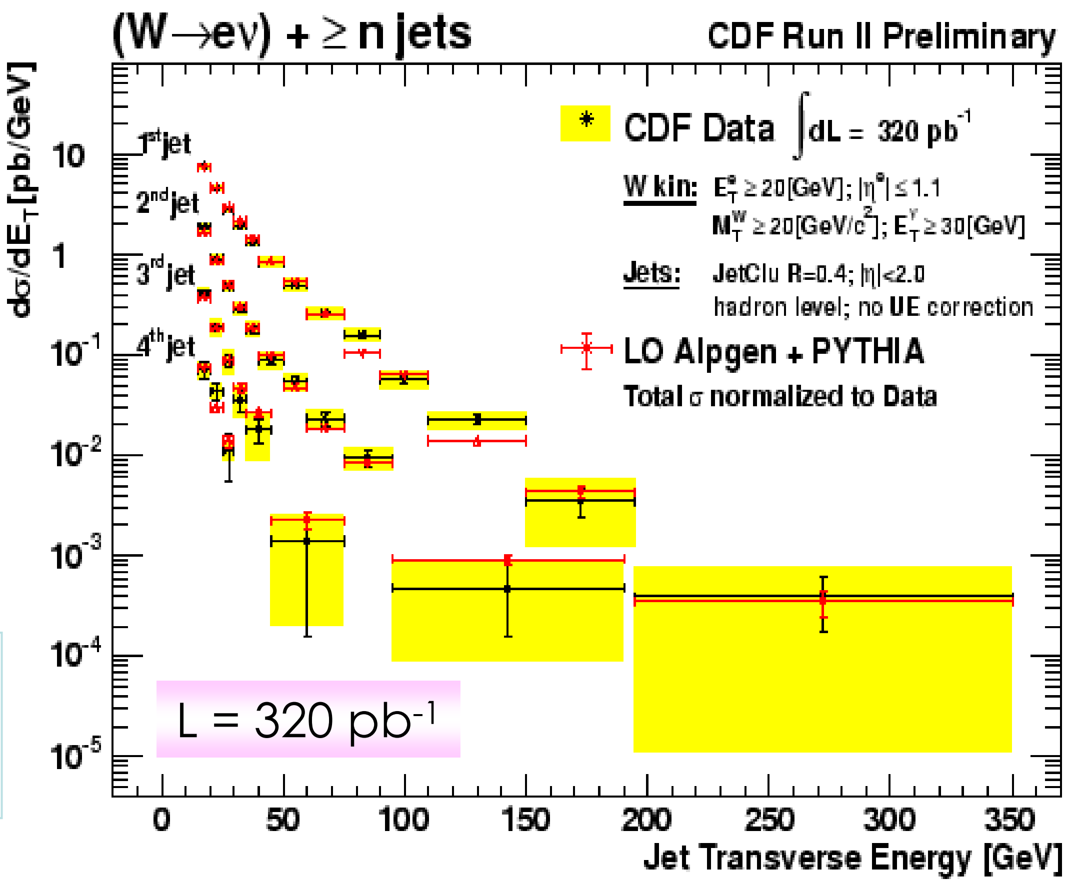
W+jets production





- Background to top and Higgs Physics
- Testing ground for pQCD in multijet environment
  - Key sample to test LO and NLO ME+PS predictions

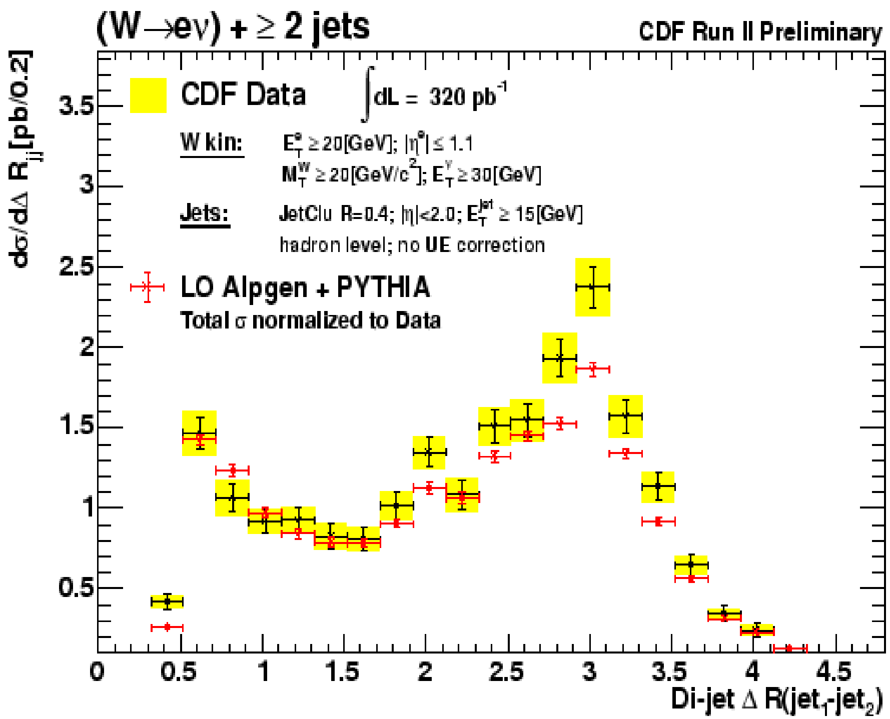
- Restrict σ_W :
  - $W \rightarrow \nu e$, $|\eta^e| < 1.1$
- JETCLU jets (R=0.4):
  - $E_T^{jets} > 15$ GeV, $|\eta^{jet}| < 2.$
- Uncertainties dominated by background subtraction and Jet Energy Scale



LO predictions normalized to data integrated cross sections

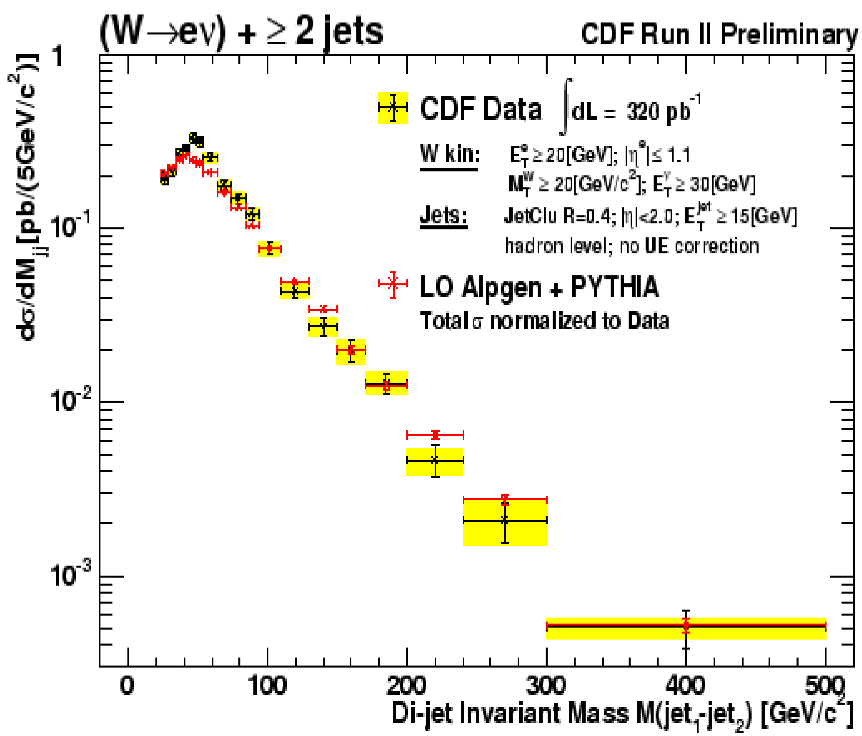
→ **Shape comparison only**

W+jets production



Differential cross section w.r.t. di-jet ΔR in the W+2 jet inclusive sample

Differential cross section w.r.t. di-jet invariant mass in the W+2 jet inclusive sample



LO predictions normalized to data integrated cross sections

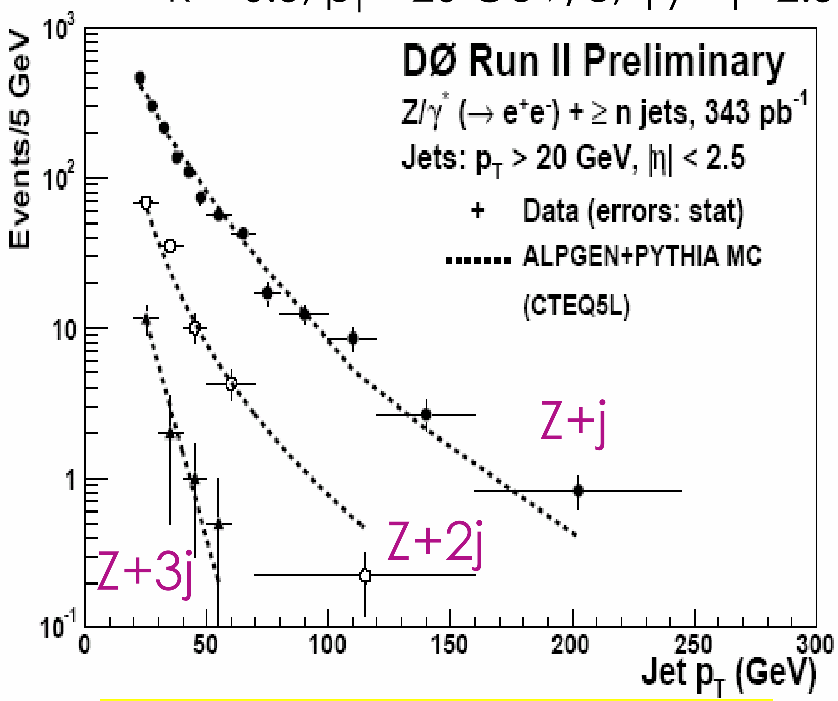
→ **Shape comparison only**

Z+jets production

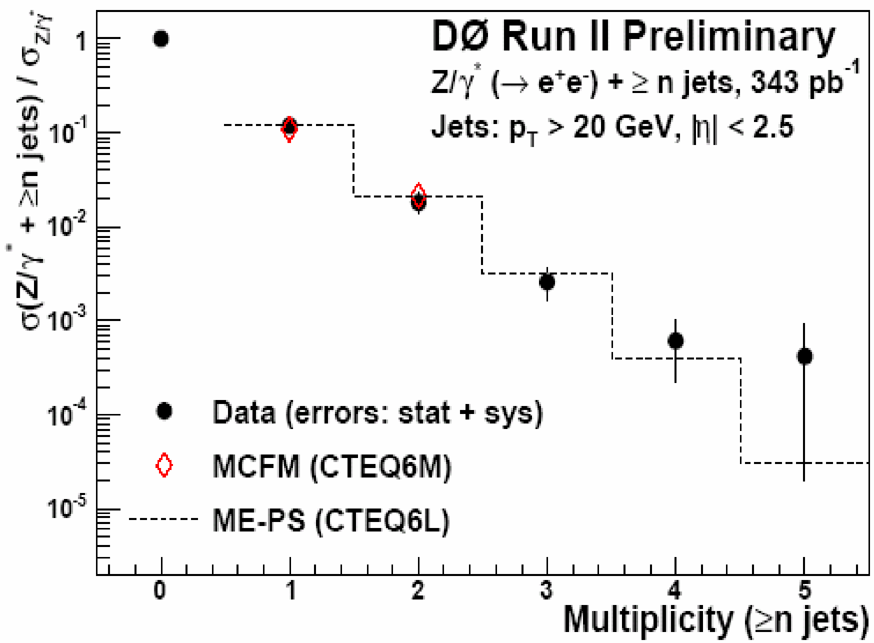
L = 343 pb^{-1}

- Same motivations as W + jets
  - σ(Z) ~ σ(W) / 10, but Z→e^+e^- cleaner
- Central electrons (|η|<1.1)
- MidPoint jets:
  - R = 0.5, p_T > 20 GeV/c, $|y^{jet}|$<2.5

$$R_n = \frac{\sigma_n}{\sigma_0} = \frac{\sigma[Z/\gamma^*(\rightarrow e^+e^-)+\geq n\,jets]}{\sigma[Z/\gamma^*(\rightarrow e^+e^-)]}$$



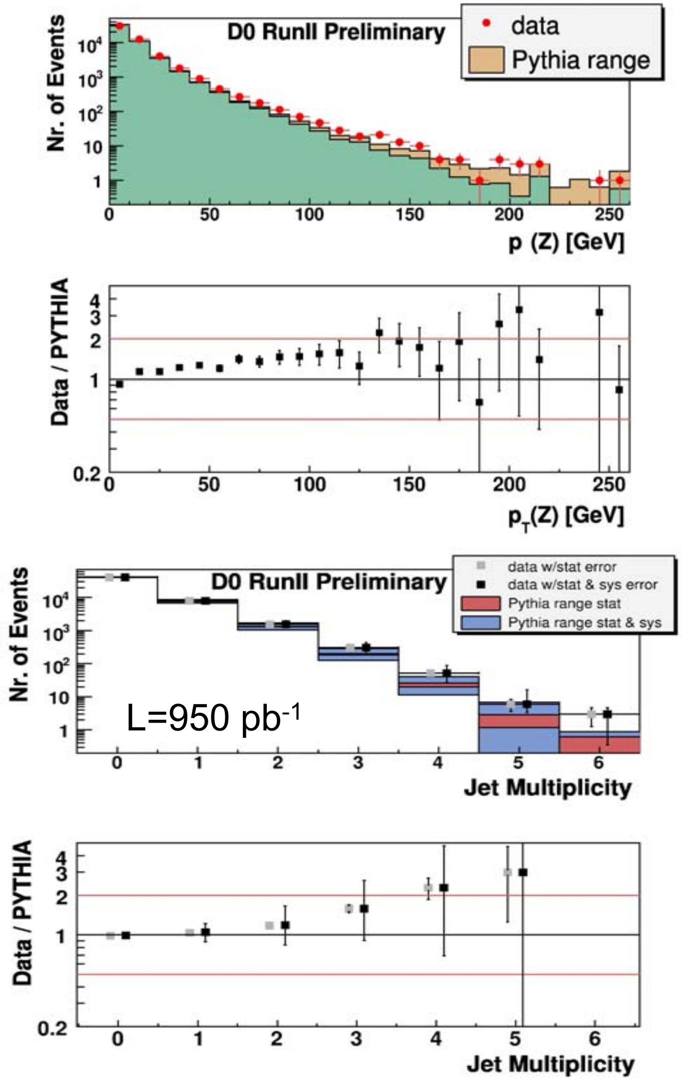
p_T spectra of n^{th} jet distribution



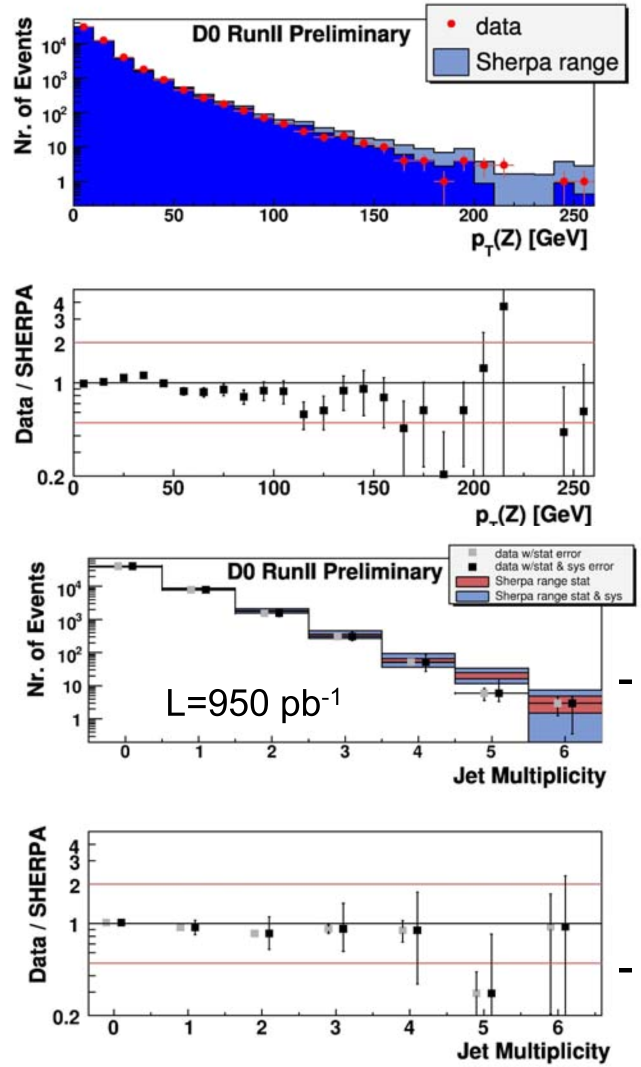
MCFM: NLO for Z+1p or Z+2p → good description of the measured cross sections

ME + PS: with MADGRAPH tree level process up to 3 partons → reproduce shape of N_{jet} distributions (Pythia used for PS)

Comparison of Sherpa (ME+PS) and Pythia(PS)



Pythia:Z+1 jets ME



Sherpa:Z+≤3 jets ME

$(Z\rightarrow ee)$+jets

L=950 pb^{-1}

- Pythia tends to under-estimate high pT jets, especially at high jet multiplicity

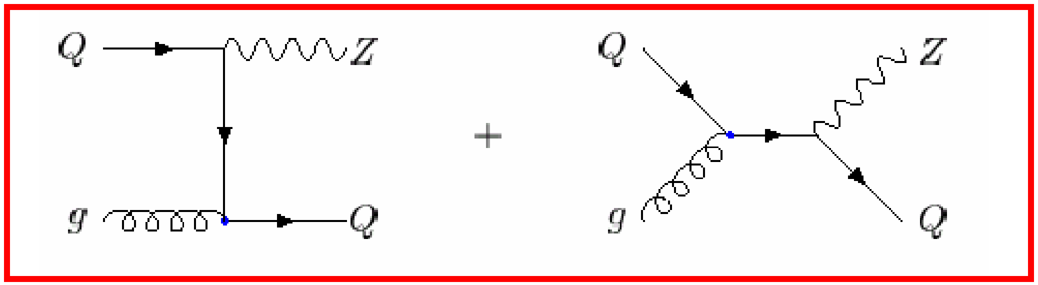
- Sherpa describes data well up to 4 jets

Z+b jet production

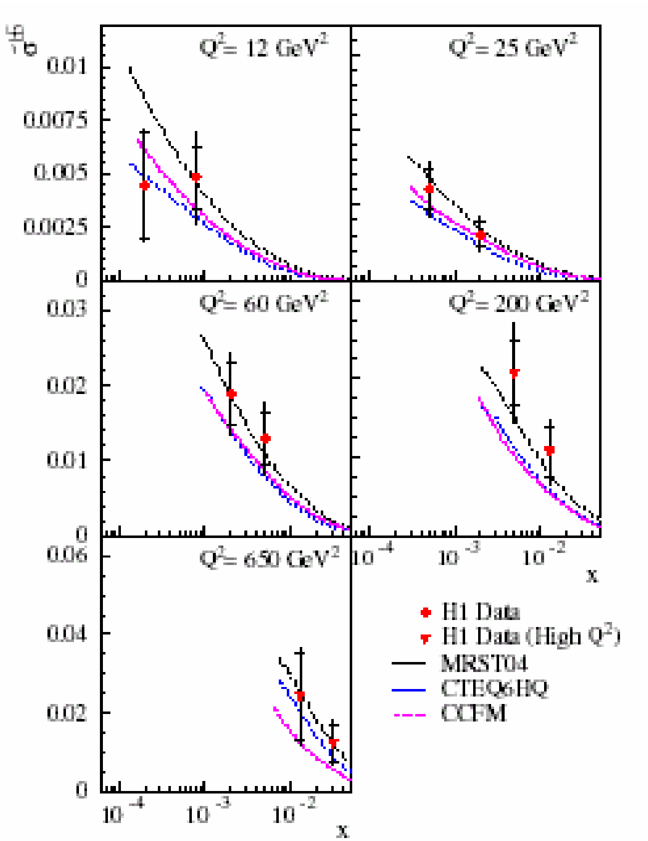
In QCD, Z+b can help constrain b density in the proton

Important background for new physics such as search for ZH Higgs production

+



Probe the heavy flavor content of proton



With HERA F^{bb}_2 data:
CTEQ below MRST by 50% and below data → Z+b jets can help understand this picture

Z+b jets production

Both CDF and D0:

- Leptonic decays for $Z \rightarrow e^+e^-, \mu^+\mu^-$
- Z associated with jets

(CDF: JETCLU, D0: MidPoint) R = 0.7, $|\eta^{jet}|<1.5$, E_T (p_T) >20 GeV

- Look for tagged jets in Z events

- Dominant systematic uncertainty:

→ B-fraction for jet events with 2 heavy quarks.

→ Jet Energy Scale

CDF

L = 335 pb^{-1}

Extract fraction of b-tagged jets from secondary vertex Mass: no assumption on the charm content

$$\sigma(Z+bjet) = 0.96 \pm 0.32 \pm 0.14 pb$$

$$R = \frac{\sigma[Z+bjet]}{\sigma[Z+jet]} = 0.0237 \pm 0.0078(stat) \pm 0.0033(syst)$$

D0

L = 180 pb^{-1}

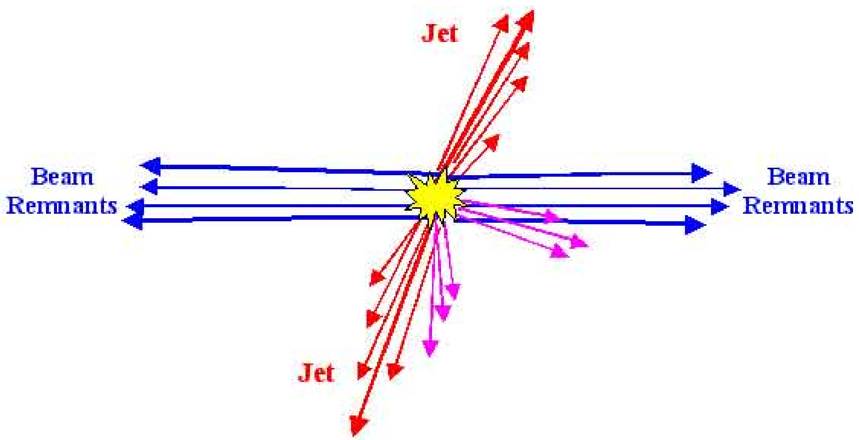
Assumption on the charm content from theoretical prediction: $N_c=1.69N_b$

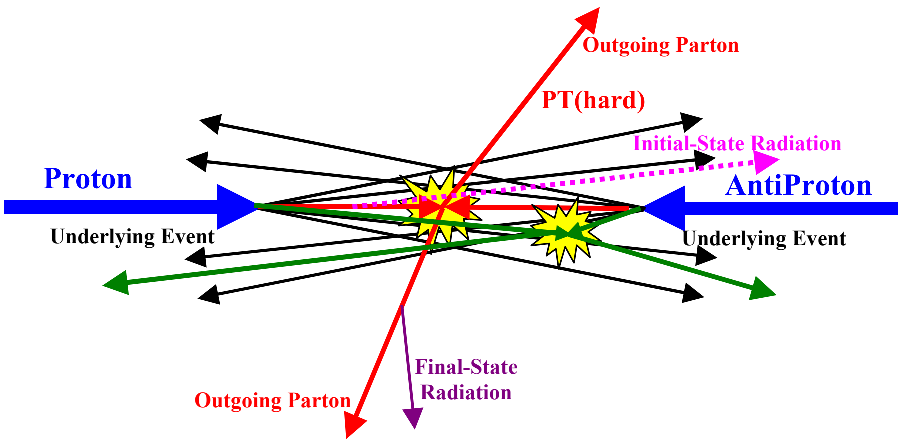
$$R = \frac{\sigma[Z+bjet]}{\sigma[Z+jet]} = 0.021 \pm 0.004(stat)^{+0.002}_{-0.003}(syst)$$

Agreement with NLO prediction: $\sigma(Z+bjet) = 0.52 pb \quad R = 0.018 \pm 0.004$

Non-Perturbative Effects

The "Underlying Event"





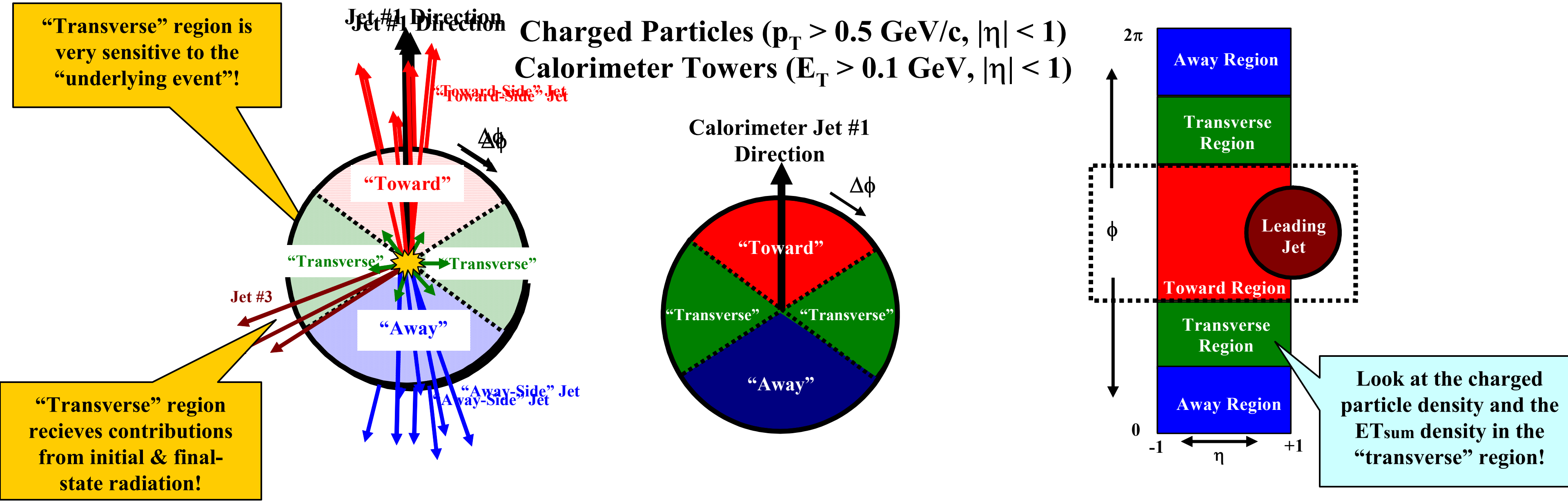
The hard scattering process:

- Outgoing two jets
- initial & final state radiation (?)

The "underlying event":

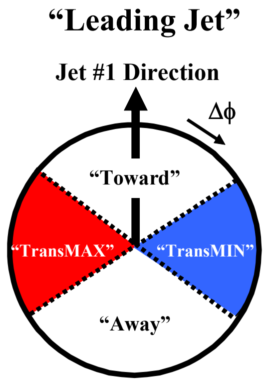
- soft initial & final-state radiation
- the "beam-beam remnants"
- possible multiple parton interactions

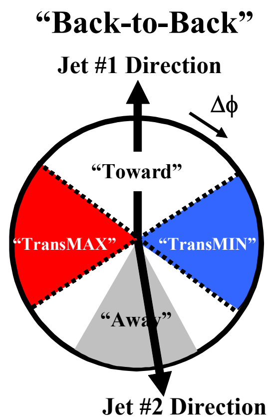
The "Transverse" Region
as defined by the Leading Jet



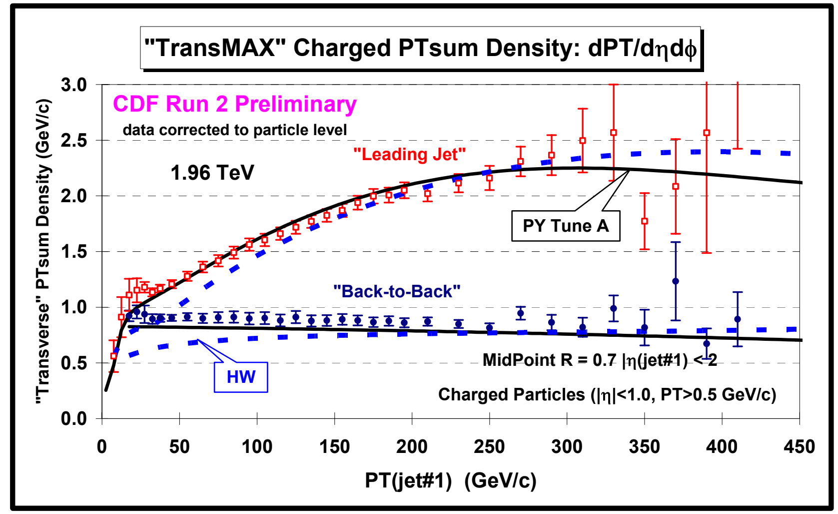
- Look at the "transverse" region as defined by the leading calorimeter jet (MidPoint, R = 0.7, f_{merge} = 0.75, |η| < 2).
- Define |Δϕ| < 60° as "Toward", 60° < -Δϕ < 120° and 60° < Δϕ < 120° as "Transverse 1" and "Transverse 2", and |Δϕ| > 120° as "Away".).
- Study the charged particles (p_T > 0.5 GeV/c, |η| < 1) and form the charged particle density, dNchg/dhdf, and the charged scalar p_T sum density, dPTsum/dηdϕ, by dividing by the area in η-ϕ space.
- Study the calorimeter towers (E_T > 0.1 GeV, |η| < 1) and form the scalar E_T sum density, dETsum/dηdϕ.

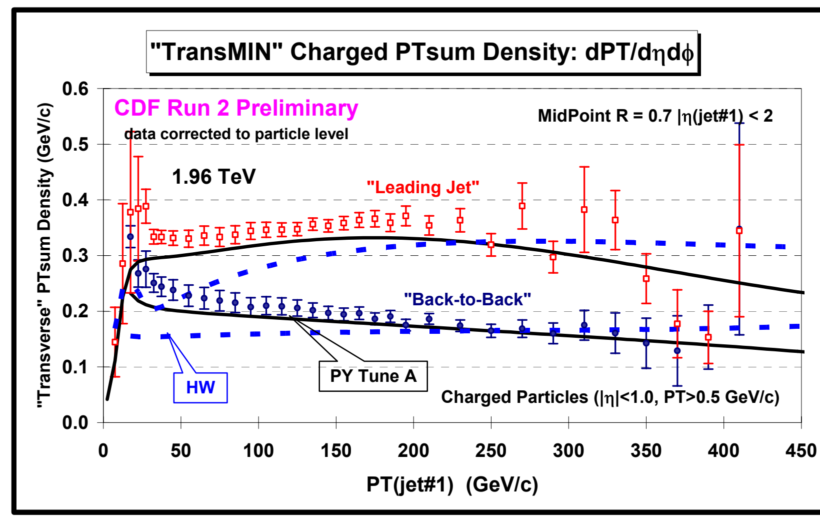
"TransMAX/MIN" PTsum Density
PYTHIA Tune A vs HERWIG





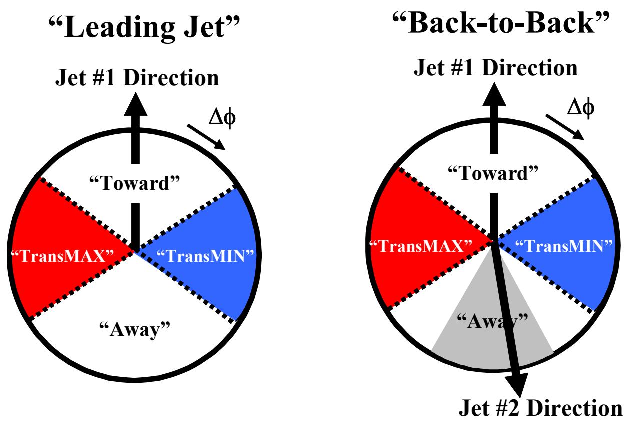
- Order transverse regions according to charged PTsum density, dPTsum/dηdφ, into "transMAX" and "transMIN" region ($p_T > 0.5$ GeV/c, $|\eta| < 1$) versus P_T(jet#1) for "Leading Jet" and "Back-to-Back" events.
- transMAX picks up the hard component
- transMIN picks up beam-beam remnant
- Compare the (*corrected*) data with PYTHIA Tune A (with MPI) and HERWIG (without MPI) at the particle level.



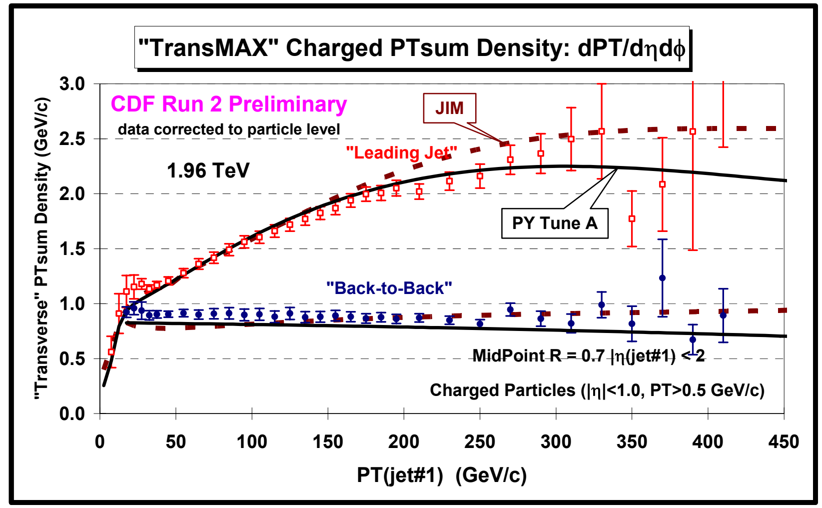


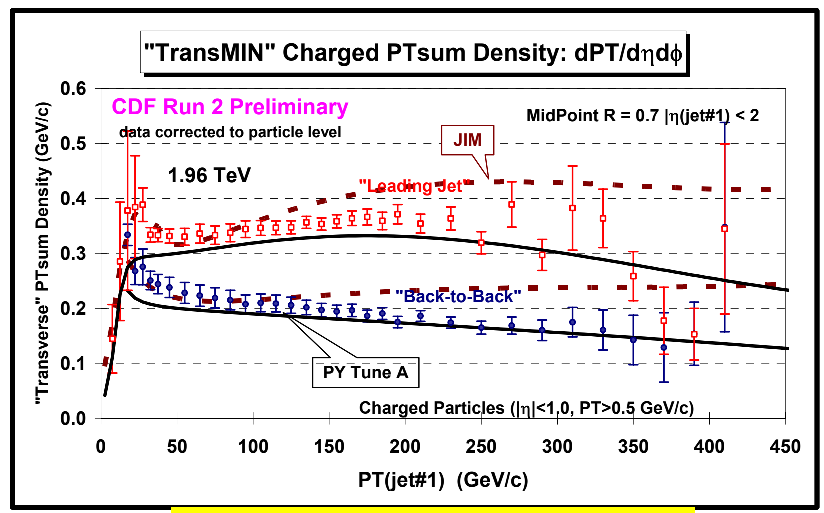
Rick Field, U of Florida

"TransMAX/MIN" PTsum Density
PYTHIA Tune A vs JIMMY



- Order transverse regions according to charged PTsum density, dPTsum/dηdφ, into "transMAX" and "transMIN" region (p_T > 0.5 GeV/c, |η| < 1) versus P_T(jet#1) for "Leading Jet" and "Back-to-Back" events.
- transMAX picks up the hard component
- transMIN picks up beam-beam remnant
- Compare the (*corrected*) data with PYTHIA Tune A (with MPI) and a tuned version of JIMMY (with MPI) at the particle level.





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Conclusions

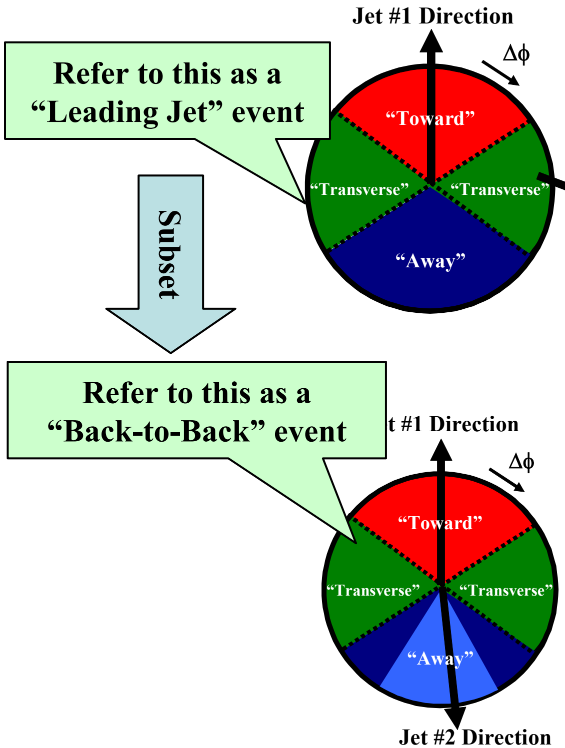
- QCD at the Tevatron is being tested in a vast kinematical range
  - 9 orders of magnitude in inclusive cross section
  - stringent pQCD tests at NLO
  - Input in global PDF fits
  - Historical Run I excesses (inclusive jet cross section and heavy flavor jet cross section) largely understood

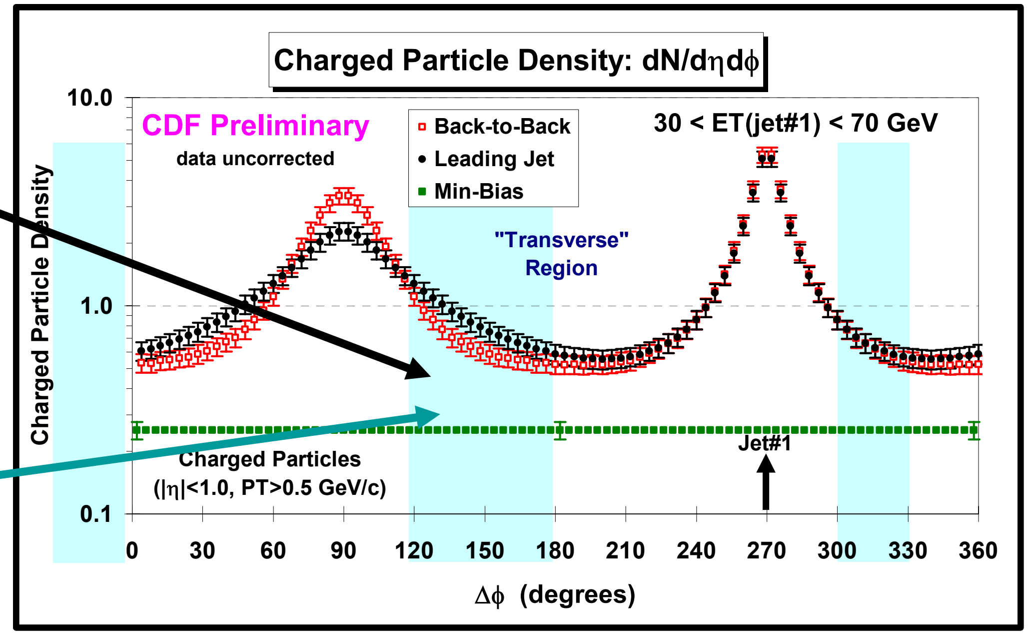
- QCD processes (especially jets +vector boson) pose significant background for searches beyond the Standard Model
  - MC tools cannot be blindly relied upon – measuring and testing a very crucial tool for future searches at the High Energy Frontier
  - QCD at the Tevatron provides a crucial testing/calibration ground for these tools (underlying event)
  - ME+PS models show good agreement – real NLO calculations (MC@NLO) very promising

- D0 and CDF are looking forward into a bright future of ~ fb^{-1} QCD physics at the Tevatron
  - QCD results amongst the first using the full data sets accumulated so far

BACKUP

Charged Particle Density
Δφ Dependence





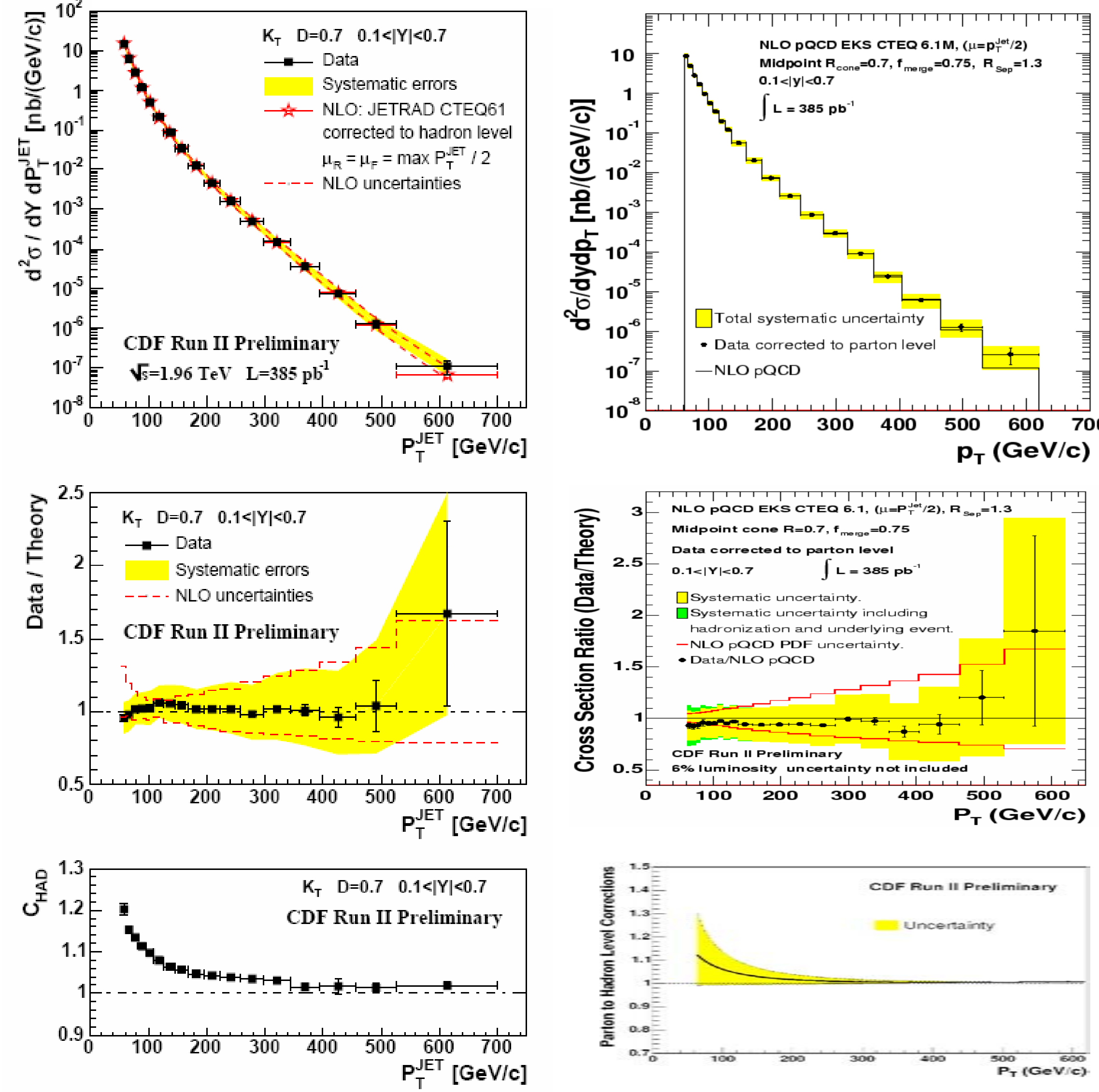
- Examine "transverse" region as defined by the leading jet ($|\eta| < 2$) or by the leading two jets ($|\eta| < 2$).
  - "Back-to-Back" events are selected to have at least two jets with Jet#1 and Jet#2 nearly "back-to-back" ($\Delta\phi_{12} > 150^o$) with almost equal transverse momenta (P_T(jet#2)/P_T(jet#1) > 0.8) and P_T(jet#3) < 15 GeV/c.

Run II Inclusive Jets: k_T vs MidPoint

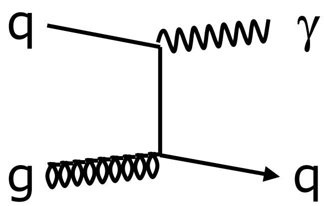
- Jet finding algorithms
  - left: kT (D=0.7)
  - right: MidPoint (R=0.7)
  - both for central jets only: 0.1<|Y|<0.7
- Comparison to NLO:
  - both agree with NLO and have similar patterns in Data/Theory
- UE+Had Corrections:
  - UE+Hadronization are phenomenological models, not a theory!
  - matter only for P_T<100
  - k_T algorithm is twice more sensitive

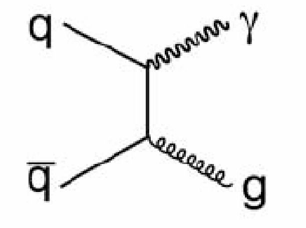
kT jet-finding algorithm

MidPoint Cone algorithm



Inclusive γ cross section (D0)



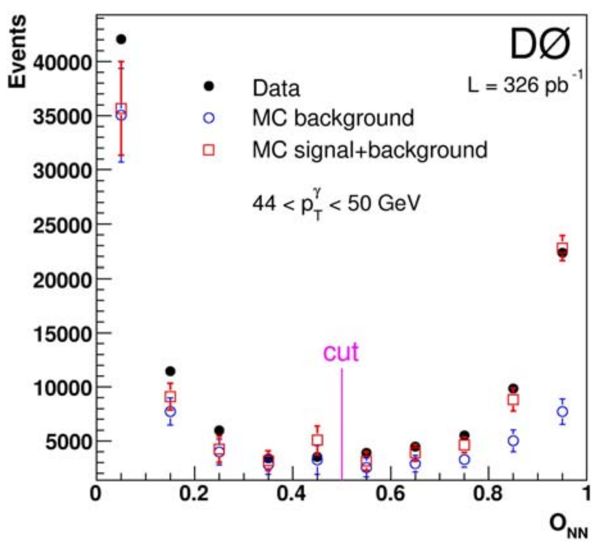


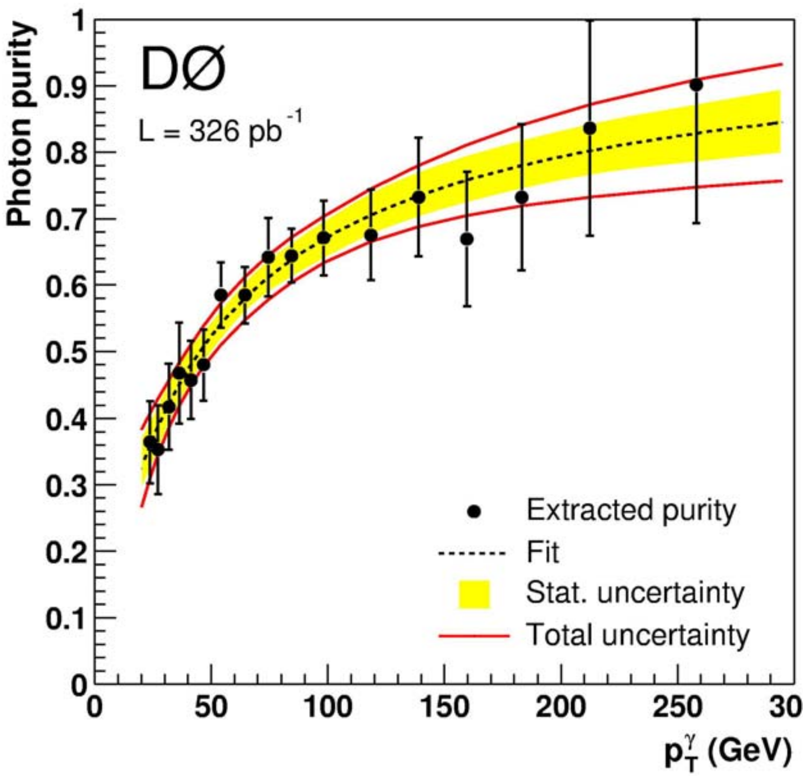
L = 330 pb^{-1}

- Sensitive to PDF and hard scatter dynamics: no need to define "jets"
- Performed for central photons, $|y^g| < 0.9$

  No Jet Energy Scale error, use good understanding of EM energy scale → purity uncertainties dominates

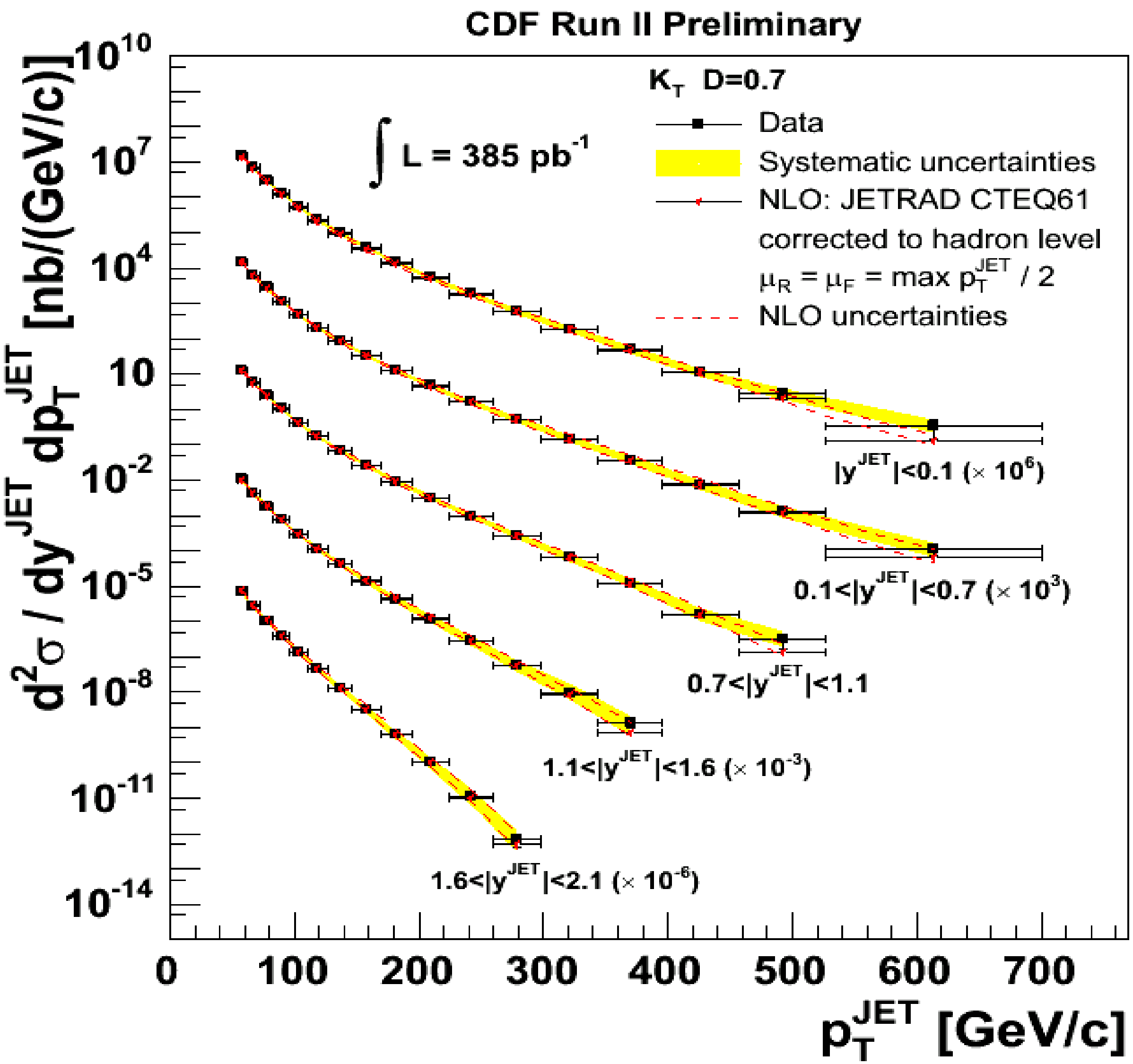
- Separating photons from jet backgrounds is challenging





- Use neural network (NN)
  - Track isolation and calorimeter shower shape variables

Forward jets (k_T algorithm ,CDF)

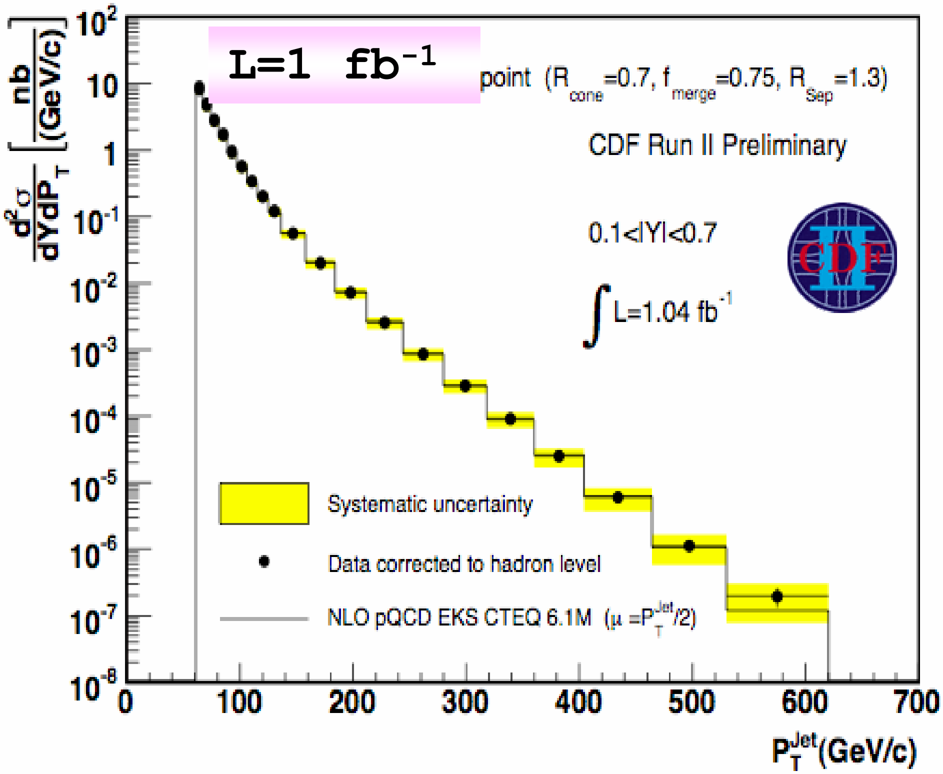


Five regions in jet rapidity explored (D=0.7):

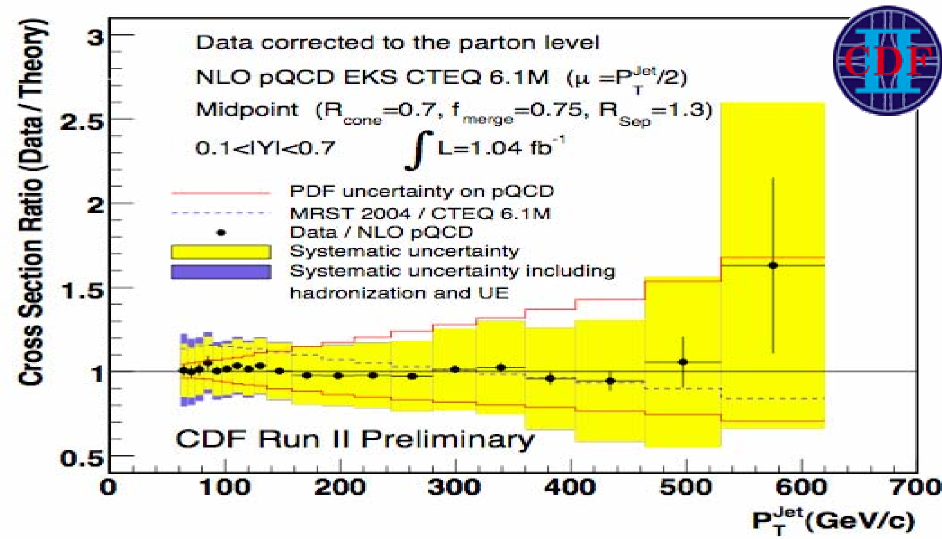
- $|y^{jet}|<0.1$
- $0.1<|y^{jet}|<0.7$
- $0.7<|y^{jet}|<1.1$
- $1.1<|y^{jet}|<1.6$
- $1.6<|y^{jet}|<2.1$

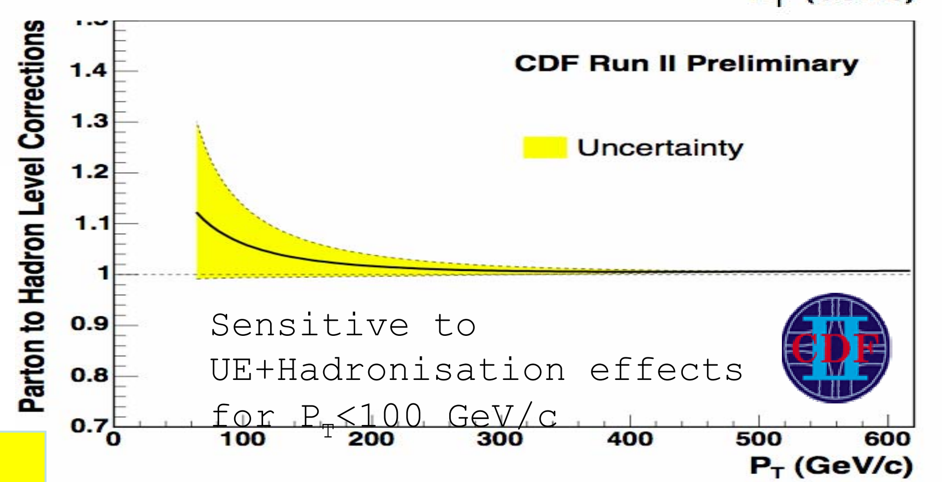
Good agreement with the NLO pQCD for jets up to $|Y|<2.1$

Inclusive Jet Cross Section-CDF (MidPoint algorithm R=0.7)



Central jets: $0.1<|y^{jet}|< 0.7$





- Systematic dominated by Jet Energy Scale uncertainties (2-3%)
- NLO uncertainty due to high x gluon PDF

Good agreement with NLO CTEQ6.1M

Run II -> MidPoint algorithm

1. Define a list of seeds using CAL towers with $E_T > 1$ GeV

2. Draw a cone of radius R around each seed and form "proto-jet"

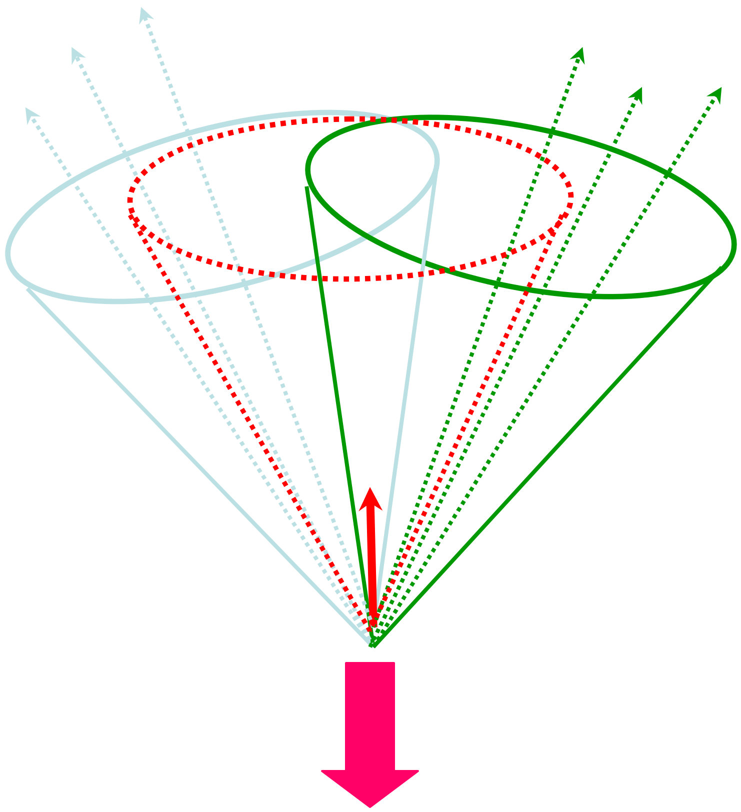
$$E^{jet} = \sum_k E^K, \quad P_i^{jet} = \sum_k P_i^K$$

(massive jets : P_T^{jet}, y^{jet})

3. Draw new cones around "proto-jets" and iterate until stable cones

4. Put seed in Midpoint $(\eta-\phi)$ for each pair of proto-jets **separated by less than 2R** and iterate for stable jets

5. Merging/Splitting



Cross section calculable in pQCD

Run I Cone algorithm

1. Seeds with $E_T > 1$ GeV

2. Draw a cone around each seed and reconstruct the "proto-jet"

$$E_T^{jet} = \sum_k E_T^k,$$

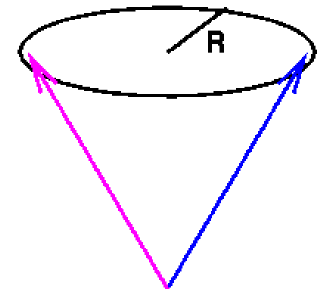
$$\eta^{jet} = \frac{\sum_k E_T^k \cdot \eta_k}{E_T^{jet}}, \quad \phi^{jet} = \frac{\sum_k E_T^k \cdot \phi_k}{E_T^{jet}}$$

3. Draw new cones around "proto-jets" and iterate until stability is achieved

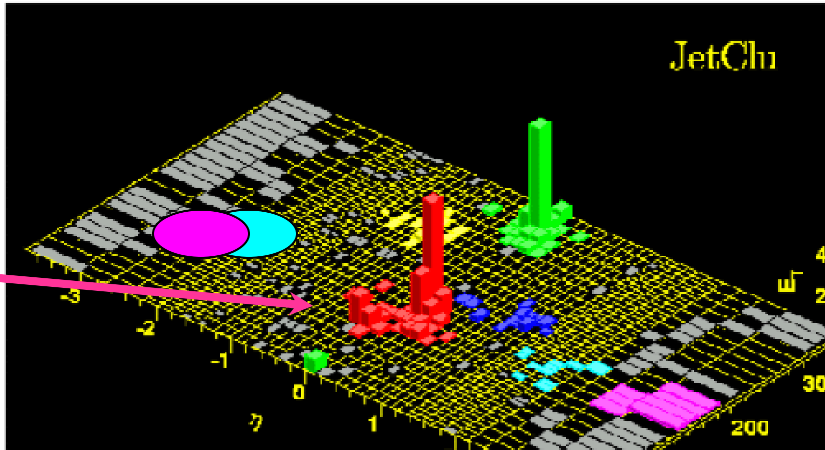
4. Look for possible overlaps

merged if common transverse energy between jets is more than 75 % of smallest jet.....

pQCD NLO does not have overlaps (at most two partons in one jet)



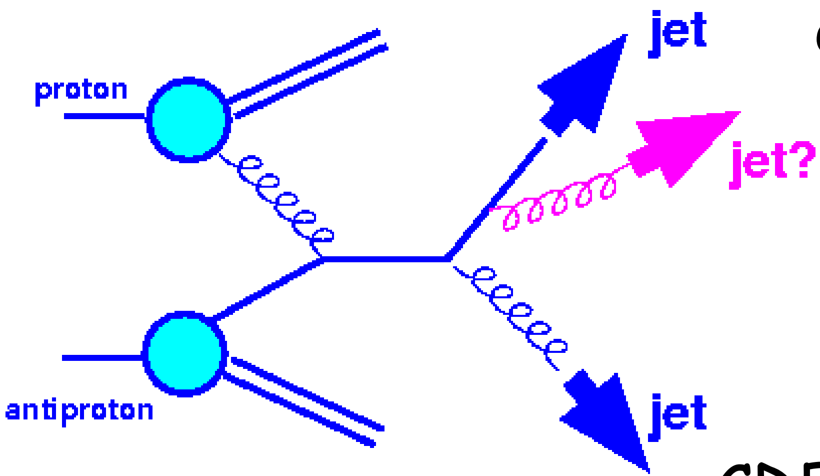
Therefore it uses larger cone R' = Rsep x R to emulate experimental procedure
-> arbitrary parameter



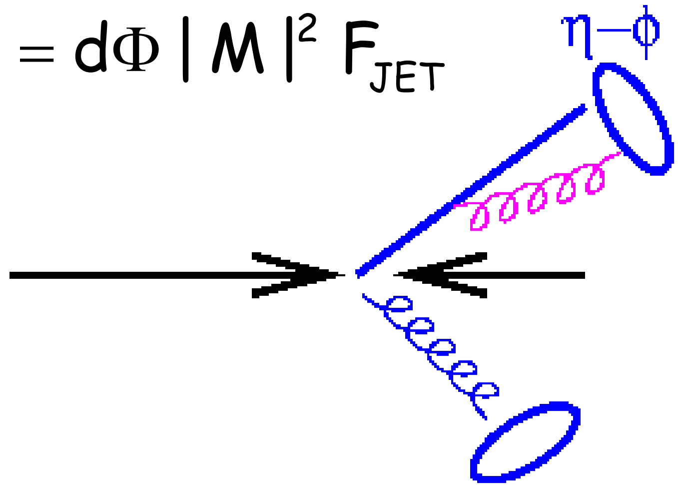
Cone algorithm

Convenient to define jets in $\eta-\phi$ space
(shape invariant against longitudinal boost)

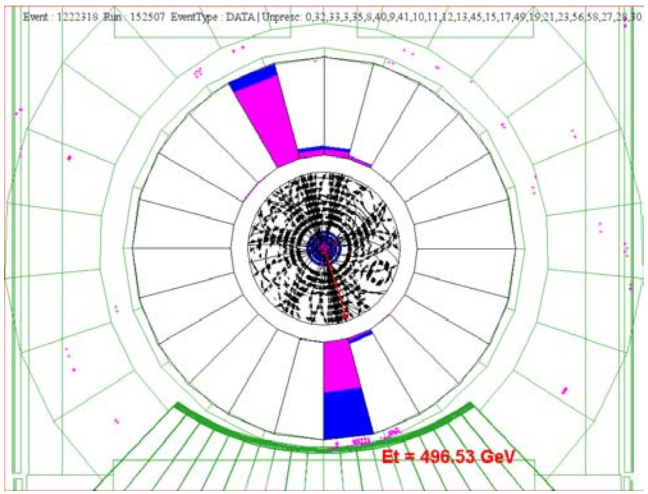
NLO pQCD diagram

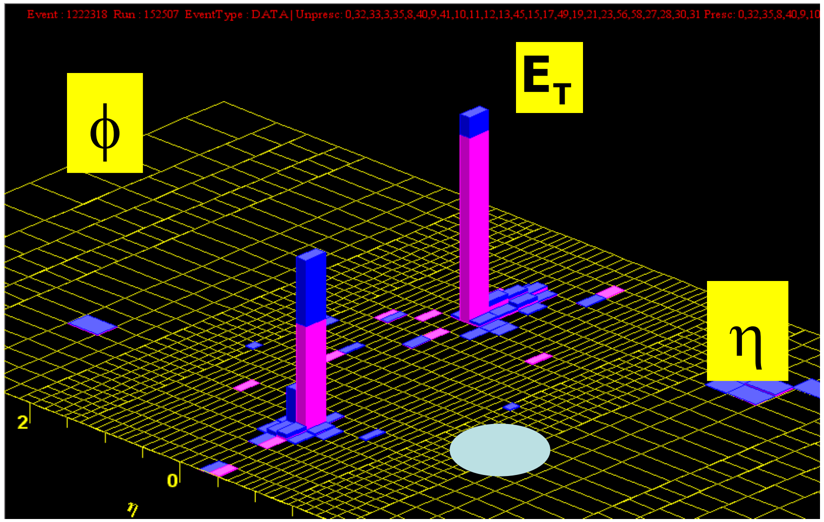


$$d\hat{\sigma}_{JET} = d\Phi\,|M|^2\,F_{JET}$$



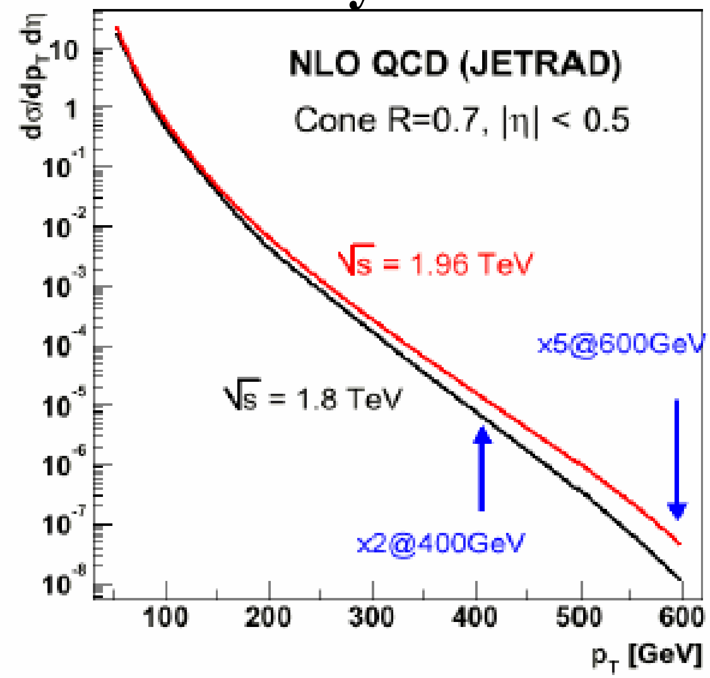
CDF



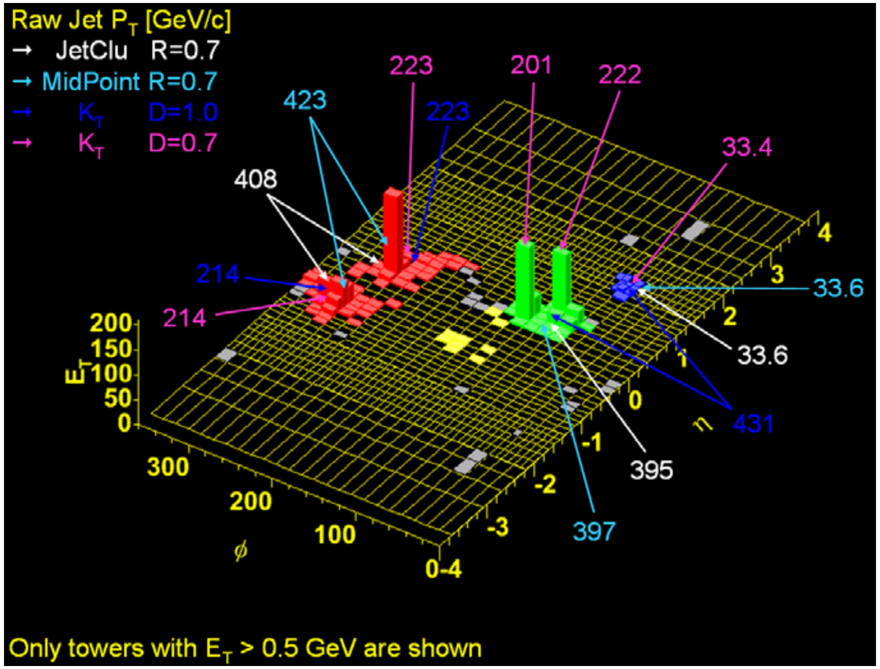


Jets at 1.96 TeV

“Theory Jets”



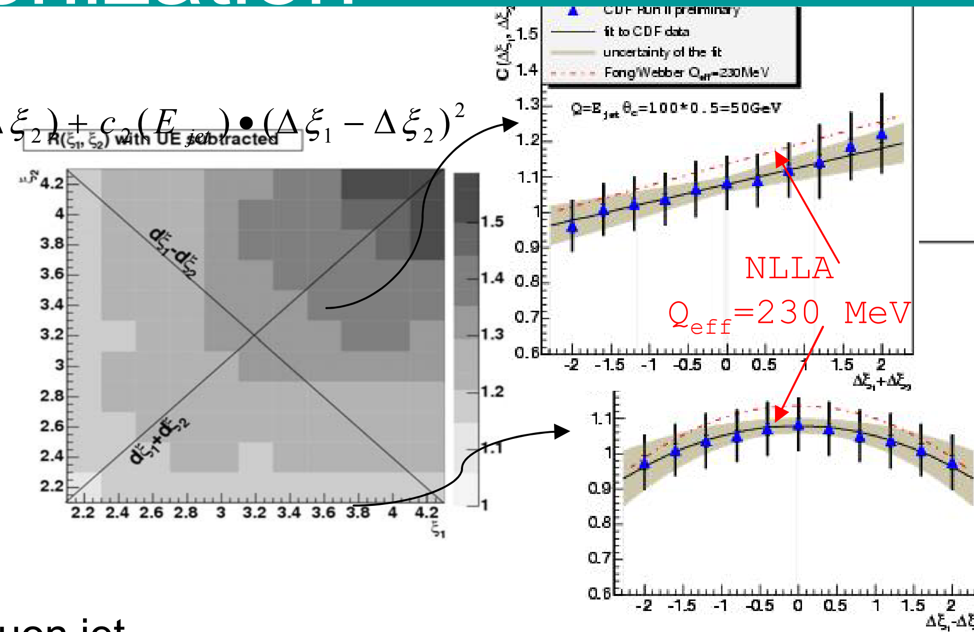
“Real Jets”



NLO parton level calculation 2->N tree level process (ALPGEN)
Mention Matching to parton shower CKKM / MLM ?
MC@NLO

Two particle momentum correlation & hadronization

$$C(\xi_1,\xi_2) = \frac{\left(\dfrac{dn}{d\xi_1 d\xi_2}\right)}{\left(\dfrac{dn}{d\xi_1}\right)\left(\dfrac{dn}{d\xi_2}\right)} = c_0(E_{jet}) + c_1(E_{jet})\bullet(\Delta\xi_1+\Delta\xi_2) + c_2(E_{jet})\bullet(\Delta\xi_1-\Delta\xi_2)^2$$



All particle pairs in cone 0.5 around the jet axis

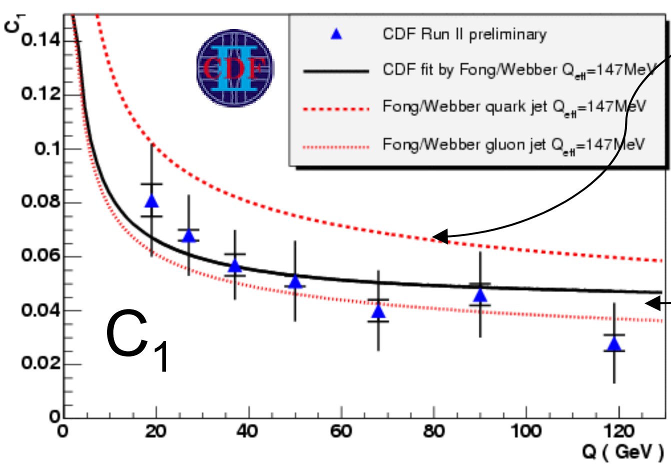
$\xi=\mathrm{Ln}(E_{jet}/P_{particle})$, $\Delta\xi=\xi-\xi^{\mathrm{At\ Max}}$

$Q=E_{jet}\times\theta_{Cone}$; Q_{eff}= parton shower cutoff in the theory

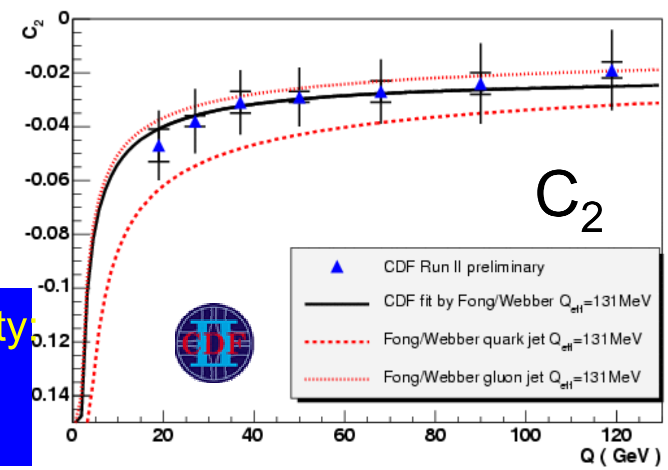
gluon jet

quark jet

$Q_{eff}\approx 150\mathrm{MeV}$

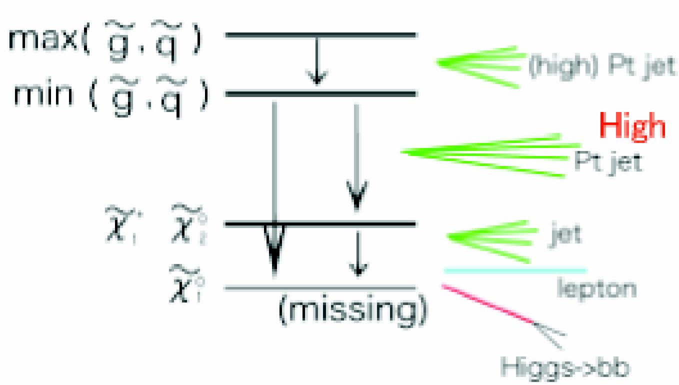


Local parton-hadron duality: correlation survives hadronization



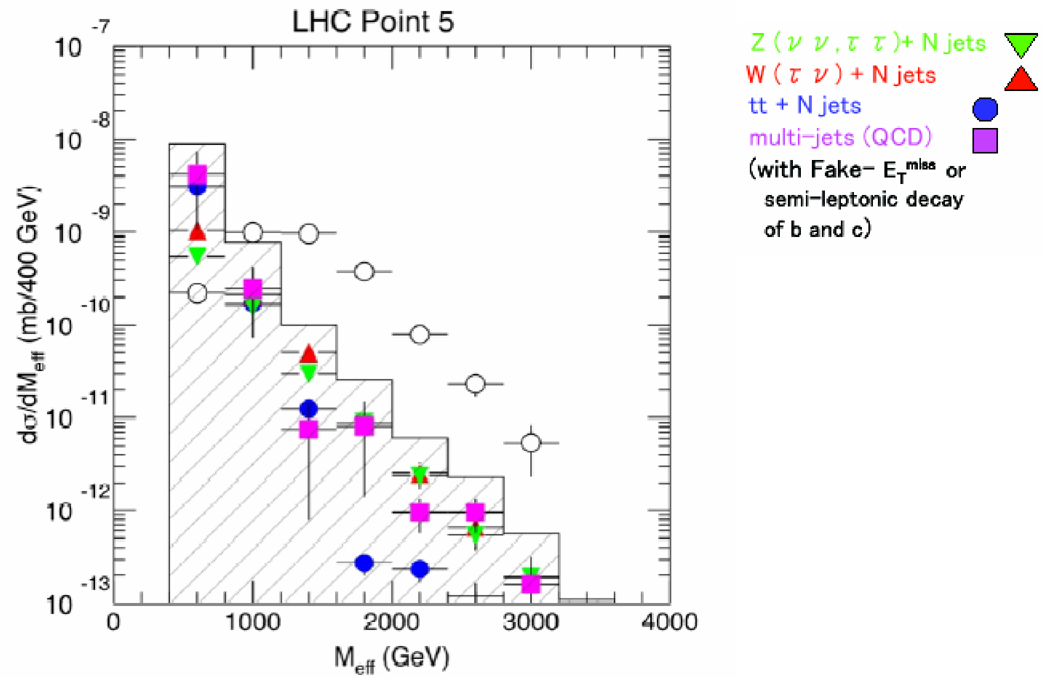
Diphoton Production

SUSY Cascade Decays @ LHC



Event topologies of SUSY are:

	multi	**leptons**
$\not{E}_T$ +	**High P_T jets** +	**b-jets**
		τ-jets

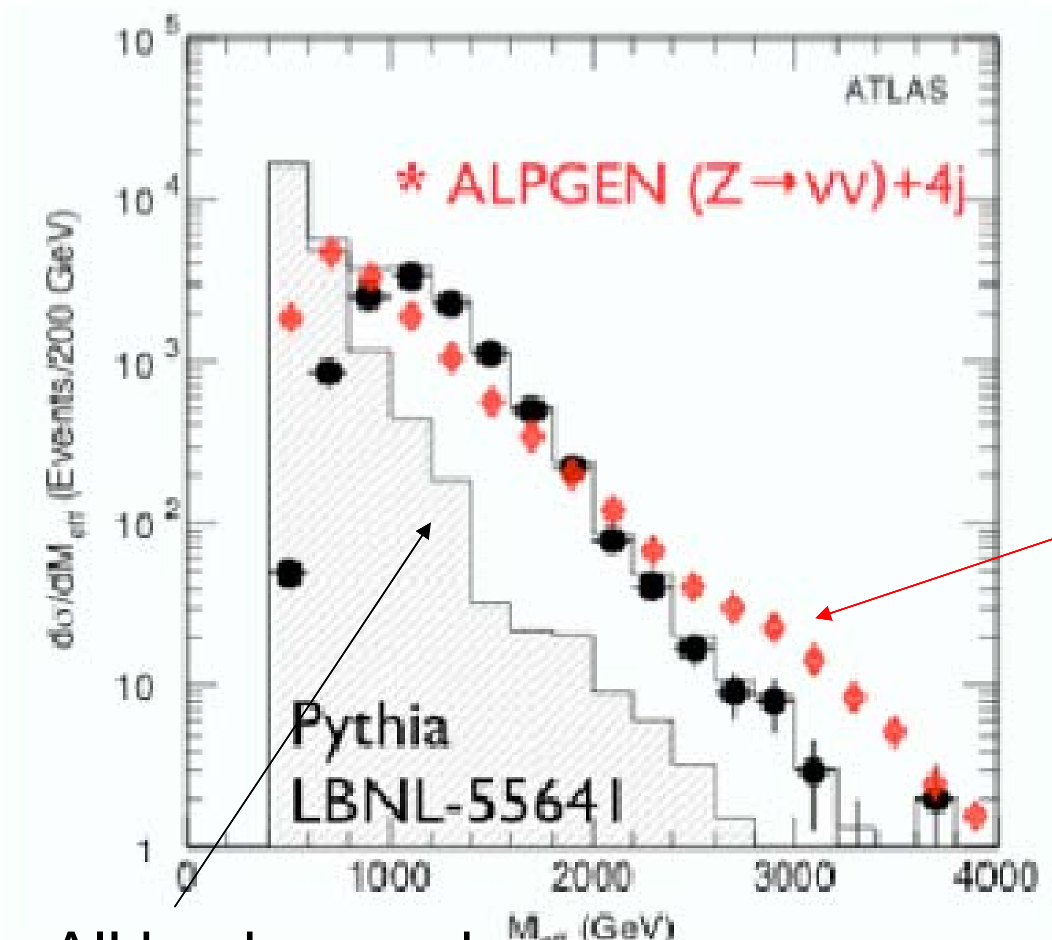


ATLAS TDR

Discovery within a month ….

Discovery within a month ?

But the SM (QCD) backgrounds are tricky!



F.Gianotti, M. Mangano
hep-ph-0504221

ME+PS (only
Z+4 jets)

All background
based on PS

Clearly, we need to understand Z/W+jets process